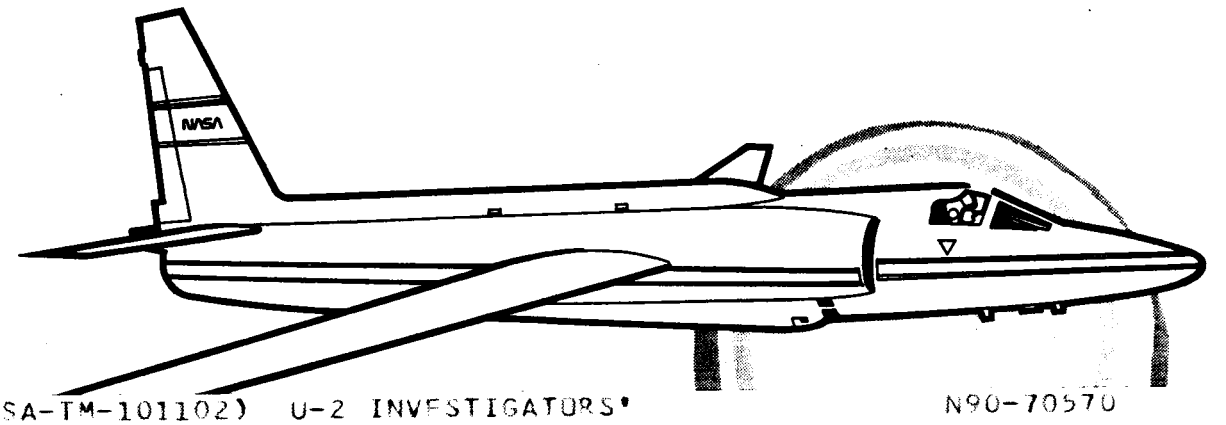

U-2 INVESTIGATORS' HANDBOOK

VOLUME II - SENSORS

PREPARED BY

AIRBORNE INSTRUMENTATION RESEARCH PROJECT

APPLICATIONS DIVISION

National Aeronautics and Space Administration • Ames Research Center • Moffett Field, California 94035

ACKNOWLEDGEMENT

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Ms. Linda Beetner
Mr. Robert Danielson
Mr. William Deming
Mr. Robert Ekstrand
Mr. William Ferguson

Martin A. Knutson
Chief
Airborne Missions & Applications Division

INTRODUCTION

The Airborne Instrumentation Research Project (AIRP) at NASA Ames Research Center, Moffett Field, California, operates two U-2 high altitude aircraft for photographic, remote sensing and the collection of other data, in support of NASA's Earth Observation Program.

Some of the operational sensors are shown in Figure i.

This handbook has been prepared to describe the wide variety of sensors operating on the U-2 and to assist interested scientists in the development and airplane integration of sensors designed by them.

The purpose of this handbook, Volumes I and II, is to aquaint existing and potential investigators with the U-2 and its capabilities. Volume I covers the airplane and outlines the requirements for equipment design and installation. Volume II describes existing operational sensors.

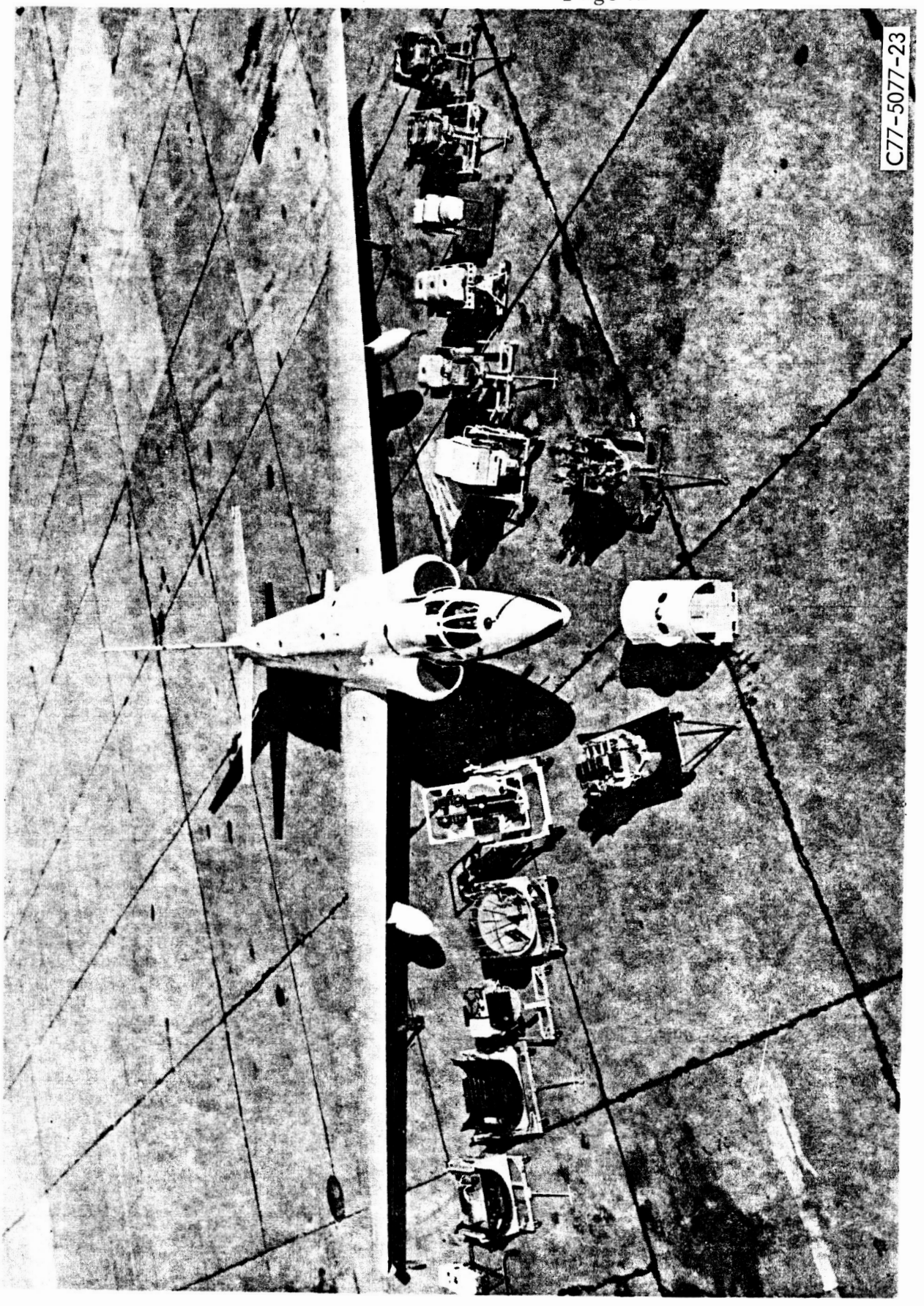

FIGURE i AIRBORNE INSTRUMENTATION RESEARCH PROJECT SENSORS

U-2 INVESTIGATORS' HANDBOOK

VOLUME II

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PHOTOGRAPHIC SYSTEMS

INTRODUCTION

Section A outlines current operational camera capabilities. A loose leaf format is utilized to allow other systems to be added, as they become available.

In addition, a planning guide to assist investigators in understanding the data mile capability of the U-2 aircraft camera systems is included herein.

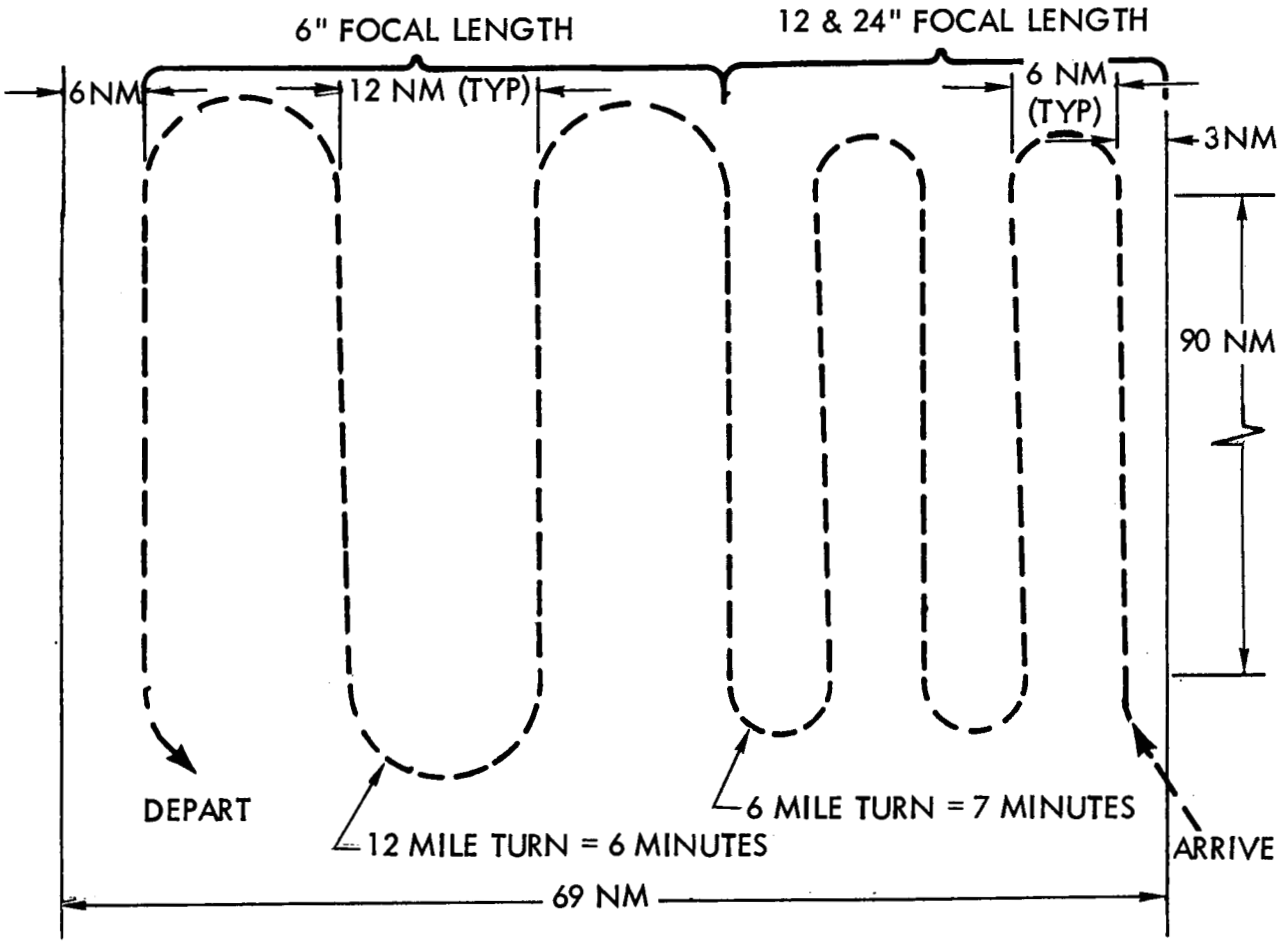
The NASA U-2 aircraft camera data acquisition capability is dependent on many variable factors, some of which are: test site location, weather, required sun angle, requested camera systems, flight line configuration, etc. Because of these factors, each data request must be handled on an individual basis, but a general understanding of the data capability can be of assistance to the investigators in their planning. For more detailed assistance in your flight planning, please contact the NASA Ames Office by telephone or letter with your specific requirements.

Airborne Instrumentation Research Project (AIRP)
NASA Ames Research Center/240-6
Moffett Field, California 94035

Phone: (415) 965-5340
965-5344
965-6562

or FTS

448-5340
448-5344
448-6562



SAMPLE TEST SITE COMPUTATION

	HRS		MIN
MAXIMUM FLIGHT DURATION	6	+	00
CLIMB AND DESCENT (SUBTRACT)	0	+	20
FLIGHT TIME REMAINING	5	+	40
DISTANCE TO AND FROM TEST SITE (SUBTRACT)	3	+	40
FLIGHT TIME REMAINING	2	+	30
TURNS BETWEEN FLIGHT LINES (SUBTRACT)	0	+	46
DATA TIME AVAILABLE	1	+	44
(AT 400 KNOTS) =	692 DATA MILES		

FIGURE A1 TYPICAL TEST SITE COMPUTATION

(SPEED OVER THE GROUND IN NORMAL WIND CONDITIONS IS 400 KNOTS)

	HRS		MIN
MAXIMUM FLIGHT TIME	6	+	00
CLIMBOUT AND APPROACH TIME (SUBTRACT)	0	+	20
FLIGHT TIME REMAINING	5	+	40
STRAIGHT LINE FLIGHT TIME TO SITE (SUBTRACT)		+	
FLIGHT TIME REMAINING			
TURN TIME BETWEEN FLIGHT LINES (SUBTRACT)			
FLIGHT TIME REMAINING			
FOR DATA ACQUISITION		+	

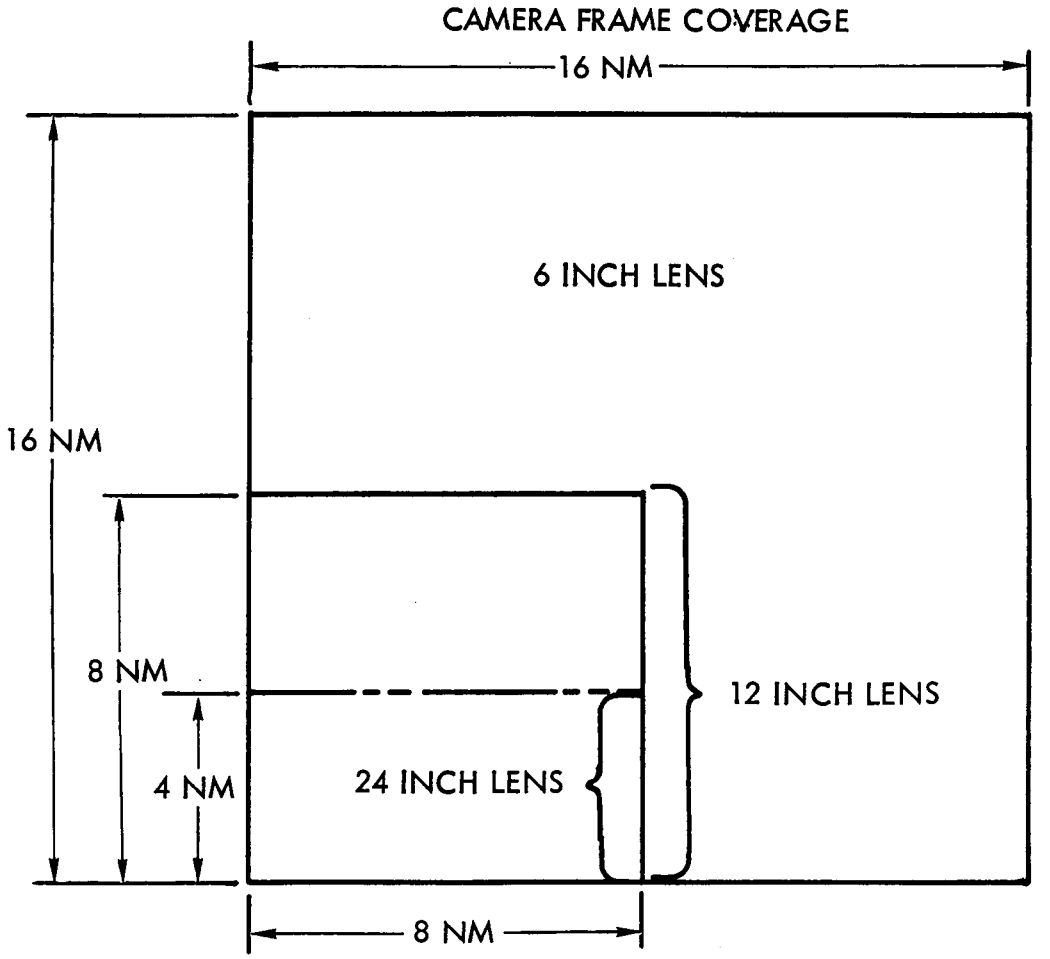


FIGURE A2 SAMPLE TEST SITE WORK SHEET

VINTEN MULTISPECTRAL CAMERA SYSTEM

The Vinten System consists of four (4) 1-3/4" focal length, 70mm, Vinten framing cameras which can spectrally simulate the Return Beam Vidicon (RBV) aboard LANDSAT. Film/filter combinations may be installed as required by specific mission requirements.

Each camera magazine is capable of a 100 foot film load or approximately 450 exposures. Overlap is controlled by an intervalometer which is variable from 2 to 120 seconds in 1 second intervals. The nominal interval is 50 seconds for a 60% overlap.

A standard filter combination results in the following spectral responses:

Camera 1	475 to 575 nanometers
Camera 2	580 to 680 nanometers
Camera 3	690 to 760 nanometers
Camera 4	510 to 900 nanometers (color infra-red)

Along the edge of each frame, fifteen (15) digits of annotation data are printed simultaneously for each camera as follows:

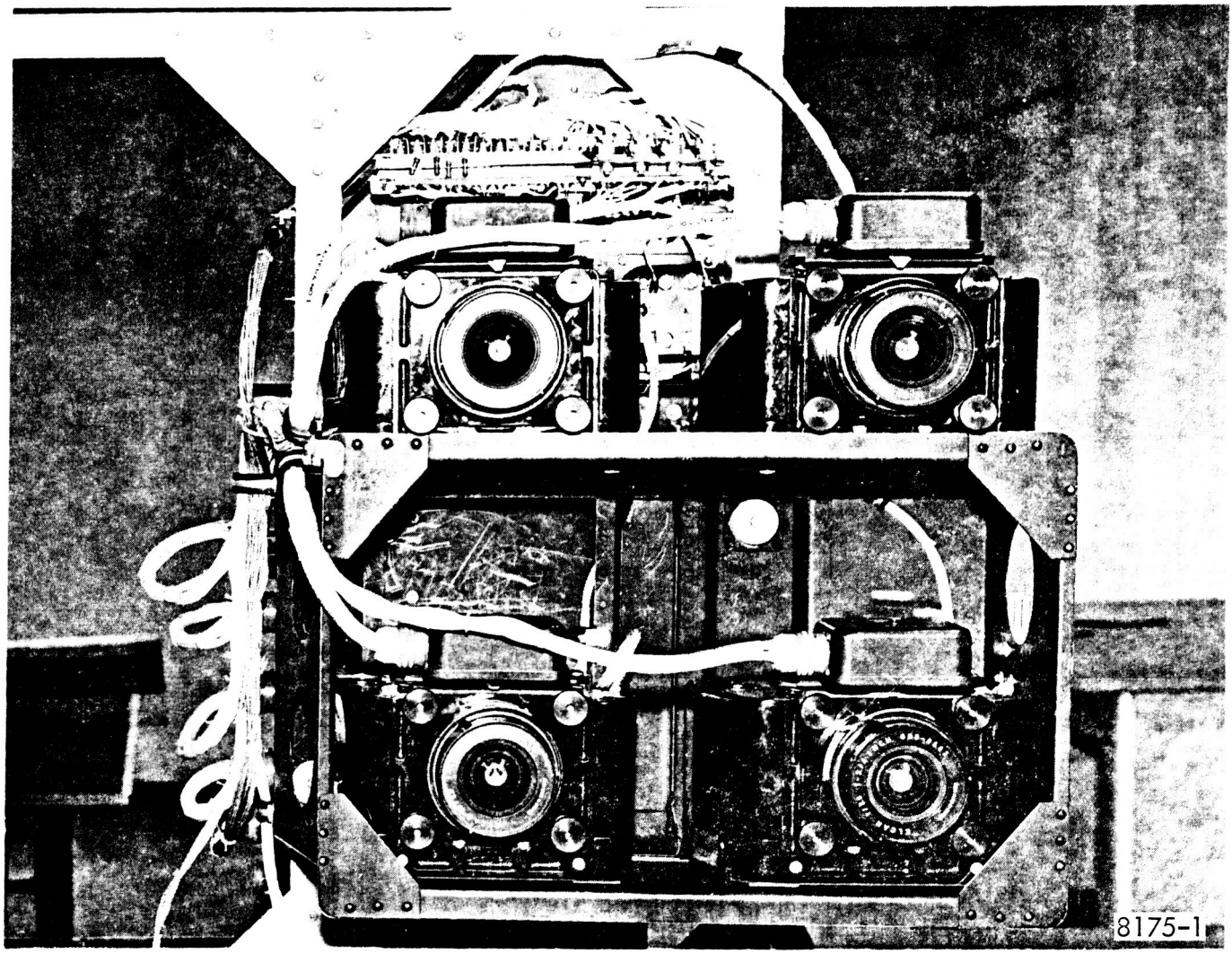
2 digits	Year
3 digits	Flight Number
1 digit	Aircraft Number
3 digits	Sensor Identification
6 digits	Time (GMT)

These Vinten Cameras are flown with a F921 type equipment bay lower hatch. (Refer to Investigators' Handbook, Volume 1). The cameras

are flown separately or have been flown simultaneously with other systems such as the RC-10, or the Ocean Color Scanner. These systems are described elsewhere in this volume. The same basic equipment bay lower hatch is used for these combinations with hatch modifications appropriate to each configuration.

Camera specifications are:

Format size	- 2-1/4 x 2-3/16 inches
Lens	- Leitz 1-3/4 inch f2.8 with an angular field of view of 64^{o} 30'
Ground coverage	- From an altitude of 65,000 ft 14 x 14 nautical miles (196 square nautical miles)
Ground resolution	- From an altitude of 65,000 ft 30 to 50 ft



CONSISTS OF:

- FOUR (4) VINTEN 1 3/4 INCH FOCAL LENGTH, 70mm LENSES
- 2 1/4 X 2 3/16 INCH FORMAT
- 70mm X 100 FT FILM
- INTERVALOMETER FOR OVERLAP CONTROL
- FRAME ANNOTATION
- GROUND RESOLUTION 30 TO 50 FT

FIGURE A3 VINTEN MULTI-SPECIAL CAMERA SYSTEM

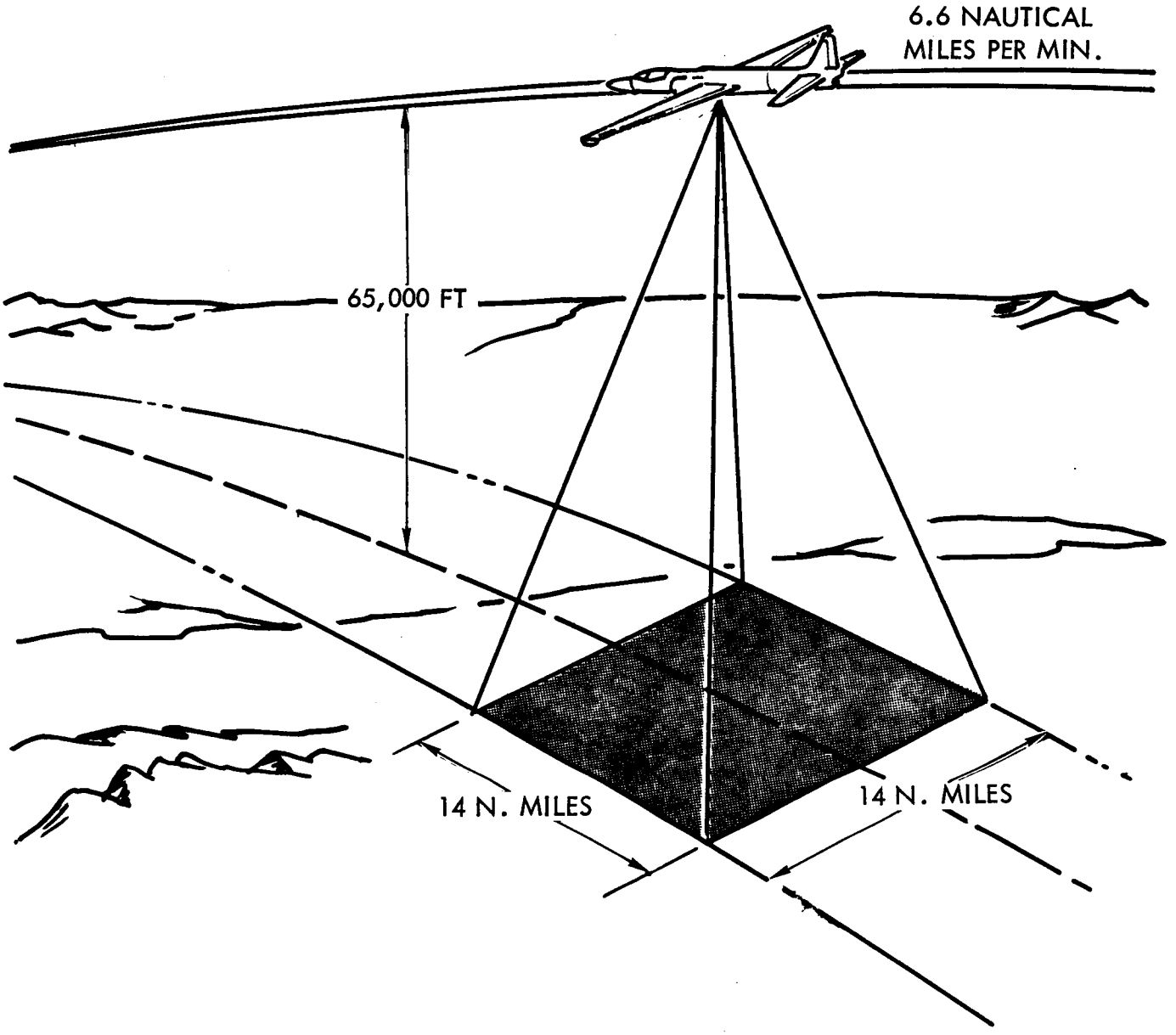


FIGURE A4 VINTEN CAMERA COVERAGE

RC-10 METRIC CAMERA

The Wild-Heerbrug RC-10 camera is a standard 9 x 9 inch format aerial camera with interchangeable 6 or 12 inch focal length lens cones. These cameras are certified for aerial mapping purposes by the U. S. Geological Survey.

The film magazine is capable of holding a 400 foot roll of film providing approximately 450 exposures. The image overlap is controlled by an intervalometer adjustable from 2 to 120 seconds in 1 second intervals. The nominal 60% overlap is 58 seconds for the 6 inch lens and 29 seconds for the 12 inch lens.

Data annotation is provided in the interframe spacing. The data is the same as that for the Vinten Cameras (Section AI).

The RC-10 is flown with an F921 equipment bay lower hatch. The RC-10 camera may be flown with the Vinten Camera System, with another RC-10 (dual RC-10 configuration), with a 24 inch HR-732 Camera system, or alone.

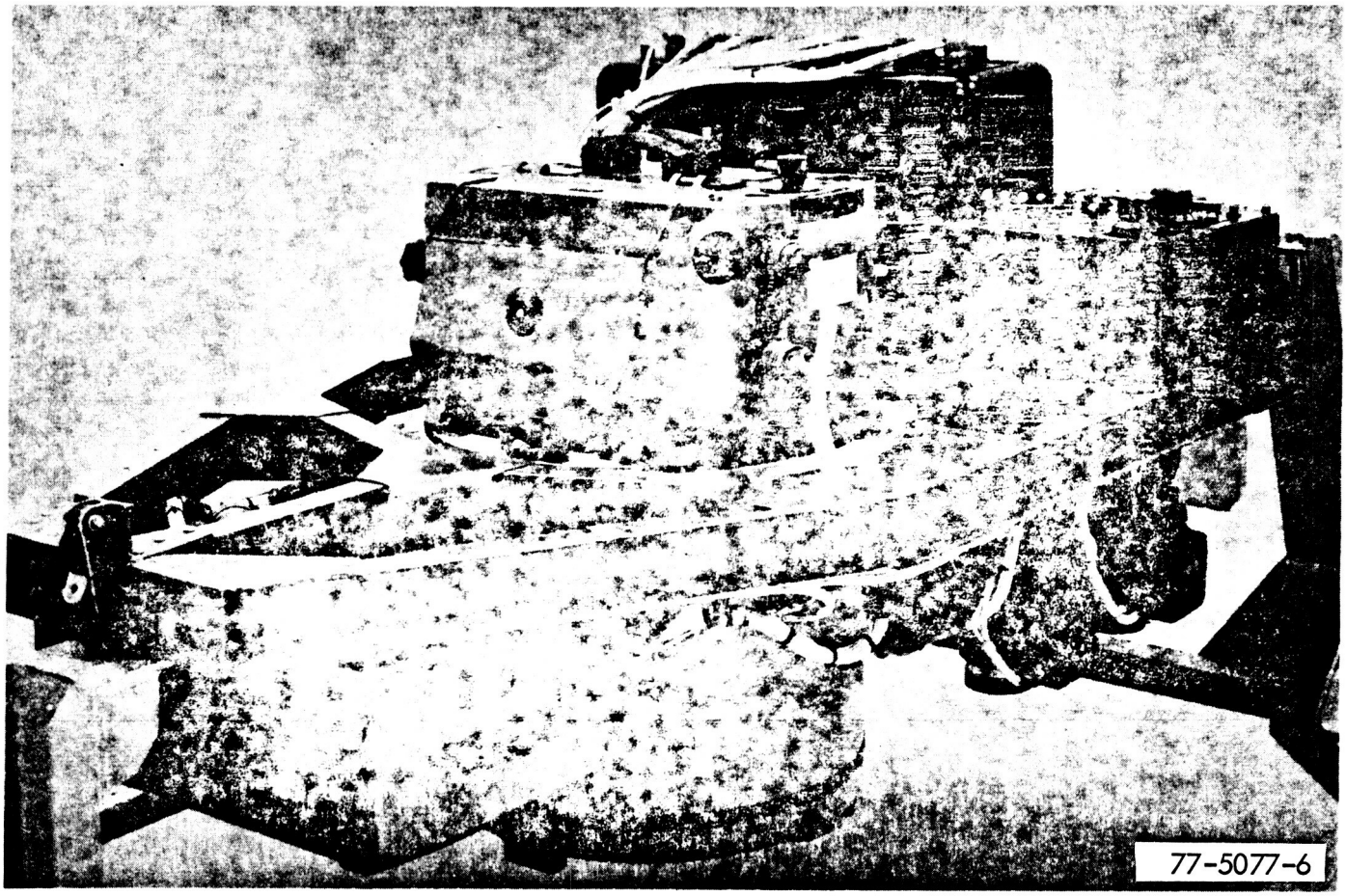
Camera specifications are:

Format size	- 9 x 9 inches
Lens	- Wild-Heerbrug Universal Aviogon II 6 inch f4, with an angular field of view of 73° 45', or an interchangeable 12 inch Aviotar II f4, with an angular field of view of 41°.

Ground Coverage - From an altitude of 65,000 ft
16 x 16 nautical miles (256 square nautical miles) for the 6 inch lens.

8 x 8 nautical miles (64 square nautical miles) for 12-inch lens.

Ground Resolution - From an altitude of 65,000 ft
15 to 25 ft for the 6 inch lens
4 to 15 ft for the 12 inch lens



CONSISTS OF:

- RC10 METRIC CAMERA
- 6 INCH OR 12 INCH FOCAL LENGTH LENS
- 9 X 9 IN FORMAT
- 9.5 INCH X 400 FT FILM
- INTERVALOMETER FOR OVERLAP CONTROL - STEREO FORMAT
- CORNER AND SIDE FIDUCIAL MARKS
- FRAME ANNOTATION
- GROUND RESOLUTION

  6 INCH LENS 15 TO 25 FT

  12 INCH LENS 4 TO 15 FT

FIGURE A5 RC-10 METRIC CAMERA

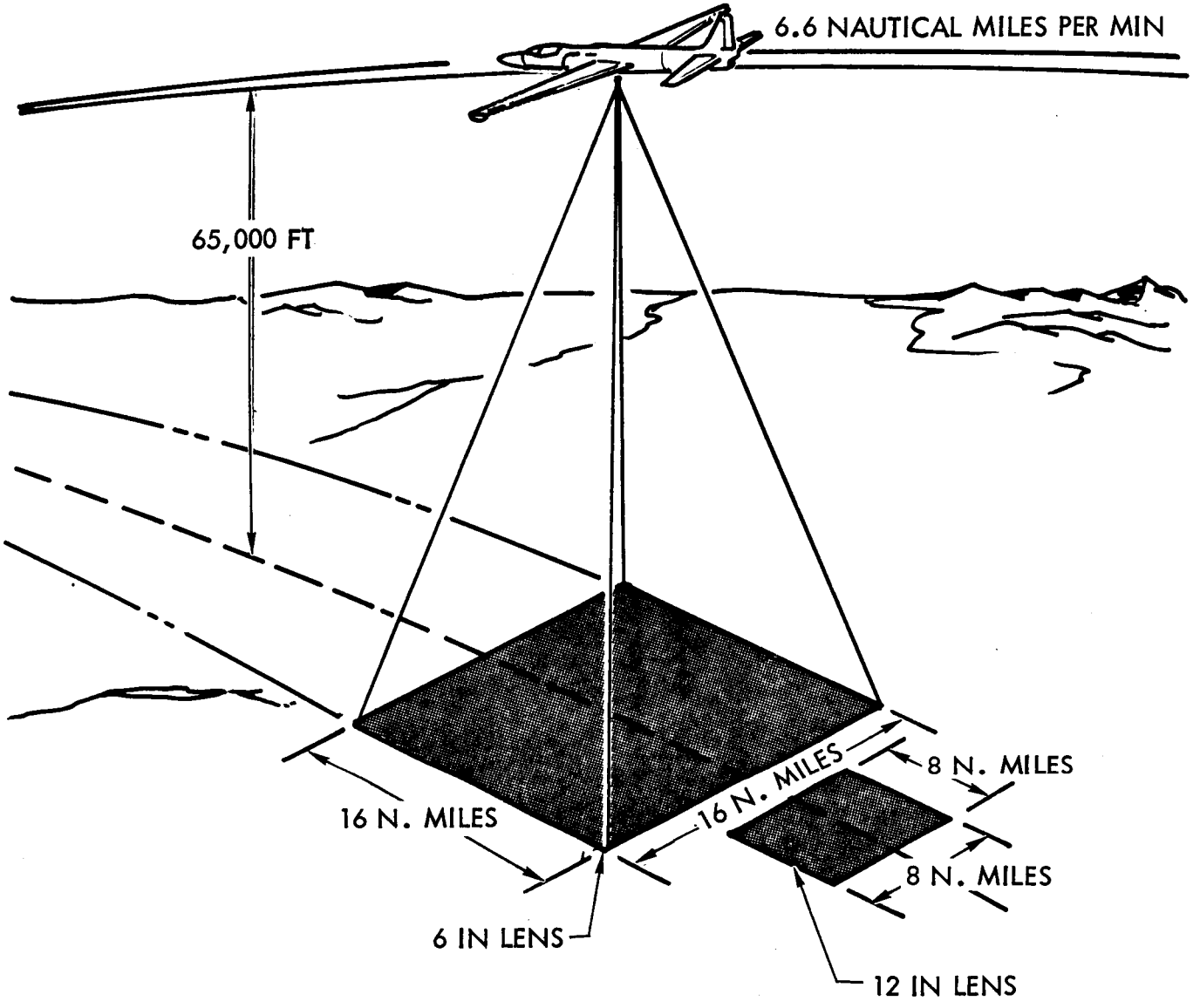


FIGURE A6 RC-10 CAMERA COVERAGE

A-3 CAMERA CONFIGURATION

The A-3 camera configuration consists of three (3) vertically mounted HR-732, 24 inch focal length cameras. The configuration allows for cameras to be operated simultaneously, singly, or in combination to allow for either extended data acquisition or multi-emulsion coverage.

Image motion conpensation (IMC) is provided for, by an IMC Assembly which rocks all three (3) cameras simultaneously. Camera operation is controlled by an intervalometer which is adjustable in 1 second intervals from 2 to 120 seconds. A nominal 60% overlap is provided by a 15 second setting of the intervalometer.

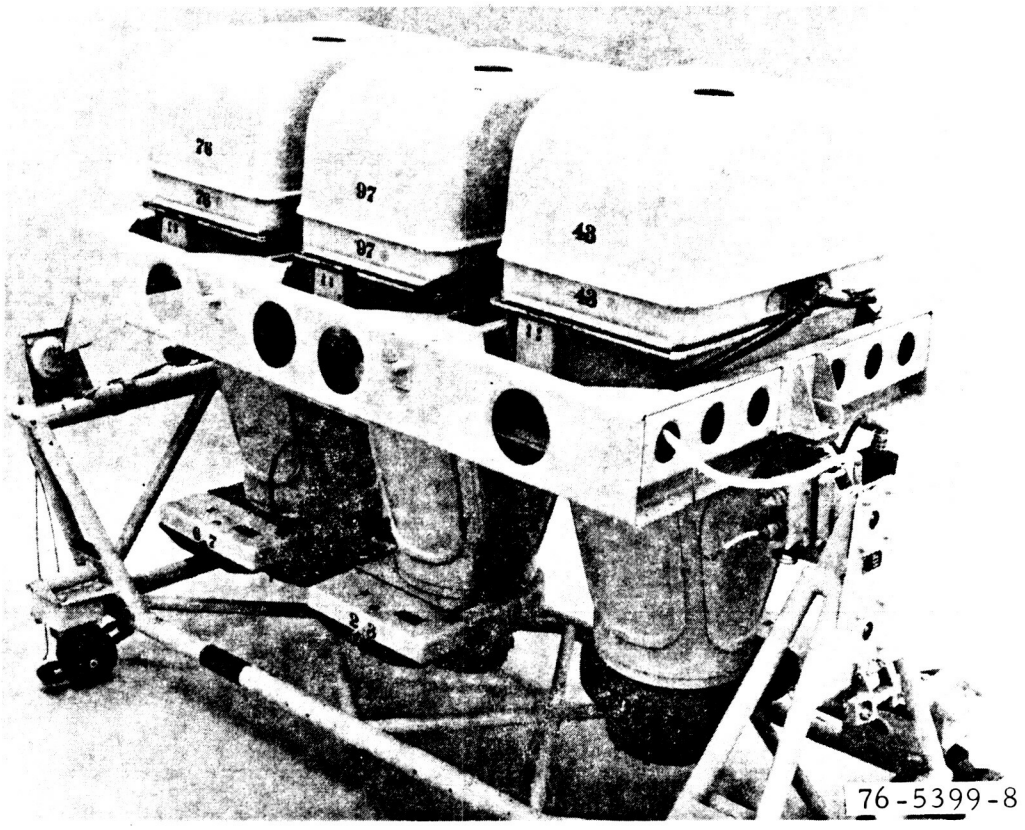
Each camera magazine is capable of holding up to 1800 feet of film or approximately 1200 exposures.

Data annotation is provided to all cameras and displayed as 15 digits. (See Section AI).

The A-3 configuration is flown with an F845 type equipment bay lower hatch. (Refer to Investigators' Handbook, Volume I).

Camera specifications are:

Format size	- 9 x 18 inches
Lens	- HR-732 24 inch f8 focal length, with an angular field of view of 41^{o} x 21^{o}.
Ground Coverage	- From an altitude of 65,000 ft 4 x 8 nautical miles (32 square nautical miles)



CONSISTS OF:

- THREE HR-732 CAMERAS
- ALL POINTING AT NADIR
- 24 INCH FOCAL LENGTH
- 9 X 18 INCH FORMAT
- 9.5 INCH X 1,800 FT FILM
- OVERLAP CONTROL - STEREO FORMAT
- GROUND RESOLUTION 2 - 8 FT.
- IMC PROVIDED BY ROCKING MOUNT FOR THREE CAMERAS SIMULTANEOUSLY
- FRAME ANNOTATION

FIGURE A7 A3 CAMERA SYSTEM

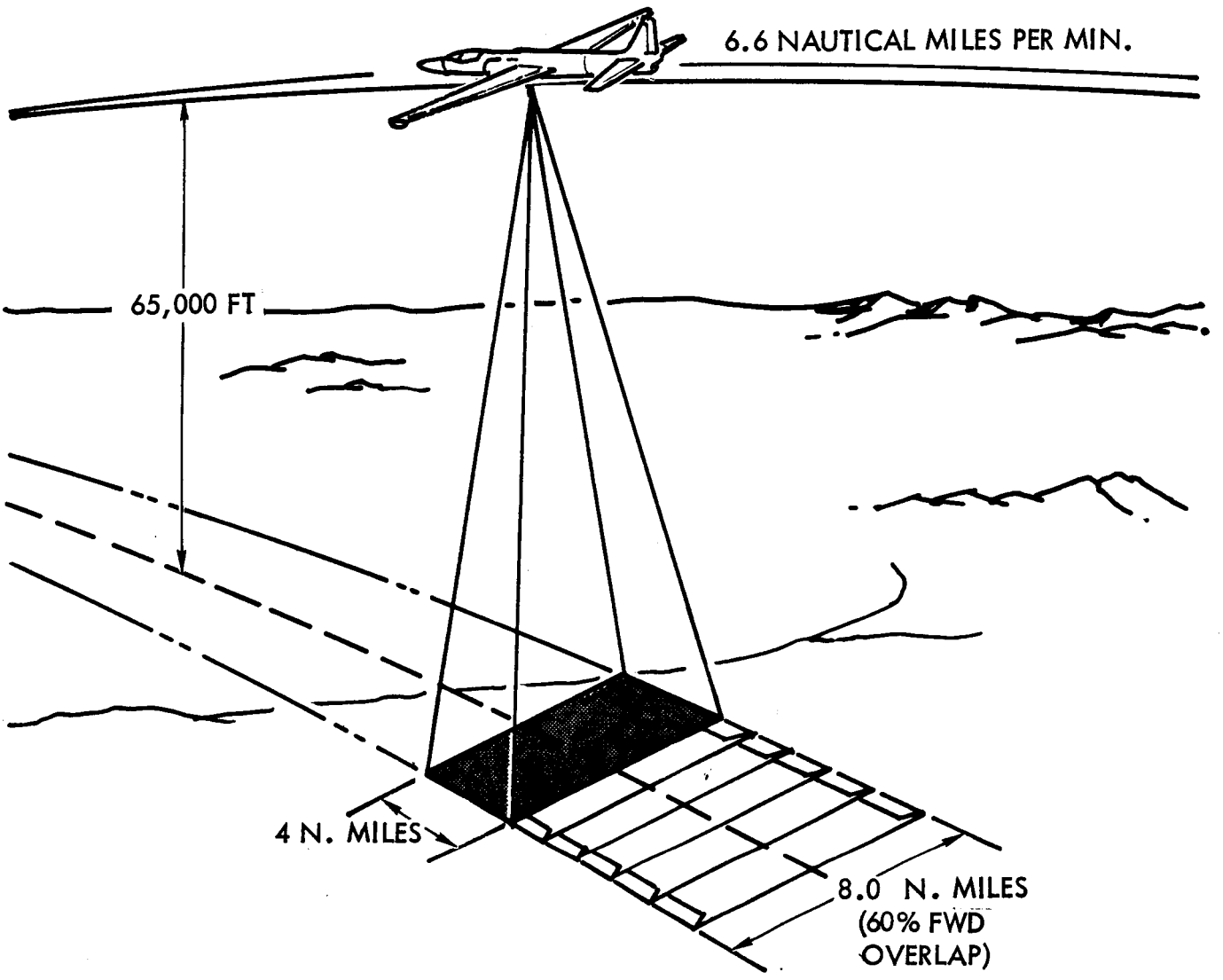


FIGURE A8 A3 CAMERA COVERAGE

A-4 CAMERA CONFIGURATION

The A-4 camera configuration consists of two (2) cameras; one (1) RC-10 and one (1) HR-732. This system is used to provide large area coverage (RC-10, 6 or 12 inch focal length) and small area, large scale coverage (HR-732, 24 inch focal length) along the same flight path.

The RC-10 camera is vertically mounted and is identical to those previously described. (See Section AII). The HR-732 camera can be operated in a vertical mode or a "rocking" mode. The rocking mode provides sequential vertical, left oblique and right oblique coverage. Image Motion Compensation (IMC) is provided on the HR-732 by an IMC assembly which rocks the camera mount during the exposure time.

Camera operation is controlled by an intervalometer and is adjustable in 1 second intervals from 2 to 120 seconds.

Data annotation is provided on all frames and is displayed as 15 digits. (See Section AI).

The A-4 configuration is flown with an EAQ80 equipment bay lower hatch. (Refer to Investigators' Handbook, Volume I).

RC-10 camera specifications are:

Format size	- 9 x 9 inches
Lens	- 6 inch f4, with an angular field of view of 73° 45' or an interchangeable 12 inch f4 lens with an angular field of view of 41°.

Ground Coverage - From an altitude of 65,000 ft 16 x 16 nautical miles (256 square nautical miles) for the 6 inch lens.

- 8 x 8 nautical miles (64 square nautical miles) for the 12 inch lens.

Ground Resolution - From an altitude of 65,000 ft 15 to 25 ft for the 6 inch lens

- 4 to 15 ft for the 12 inch lens

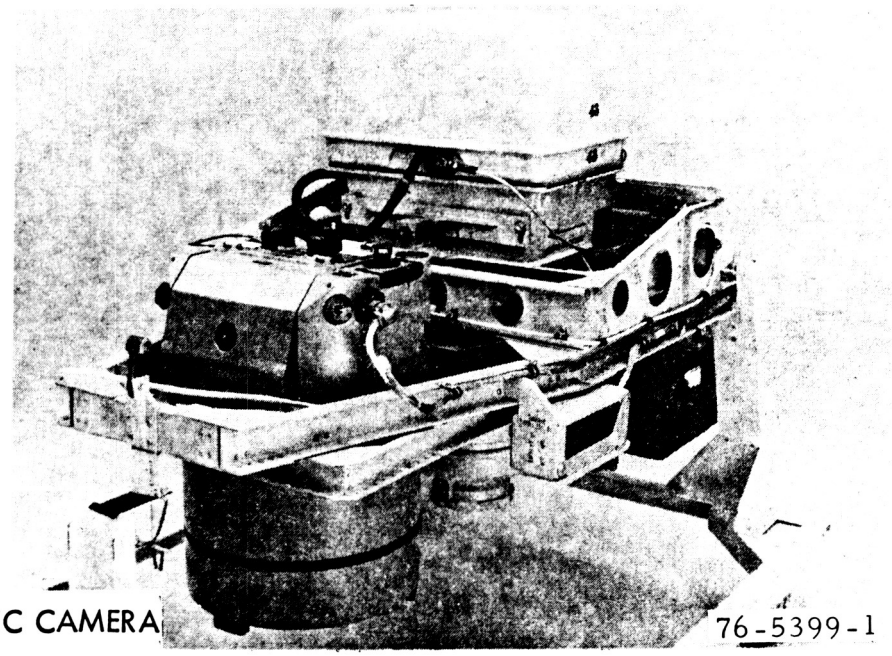
HR-732 camera specifications are:

Format size - 9 x 18 inches

Lens - 24 inch f8, with an angular field of view of 41^{o} x 21^{o}. The centerline of the field of view for the oblique positions is 37^{o} off the vertical.

Ground coverage - From an altitude of 65,000 ft 4 x 8 nautical miles (32 square nautical miles for the vertical mode and 33.5 square nautical miles for the three (3) positions in the rocking mode.

Ground resolution - From an altitude of 65,000 ft 2 to 8 ft



CONSISTS OF:

- RC-10 METRIC CAMERA
  - 6 INCH OR 12 INCH FOCAL LENGTH LENS
  - 9 X 9 INCH FORMAT
  - 9.5 INCH X 400 FT FILM
  - INTERVALOMETER FOR OVERLAP CONTROL - STEREO FORMAT
  - CORNER AND SIDE FUDICIAL MARKS
  - FRAME ANNOTATION
  - GROUND RESOLUTION
    - 6 INCH LENS 15 TO 25 FT.
    - 12 INCH LENS 4 TO 15 FT.
- HR-732 CAMERA
  - 24 INCH FOCAL LENGTH LENS
  - 9 X 18 INCH FORMAT
  - 9.5 INCH X 1800 FT. FILM
  - INTERVALOMETER FOR OVERLAP CONTROL - STEREO FORMAT
  - FRAME ANNOTATION
  - GROUND RESOLUTION 2 - 8 FT.
  - IMC PROVIDED BY ROCKING MOUNT

FIGURE A9 A4 CAMERA SYSTEM

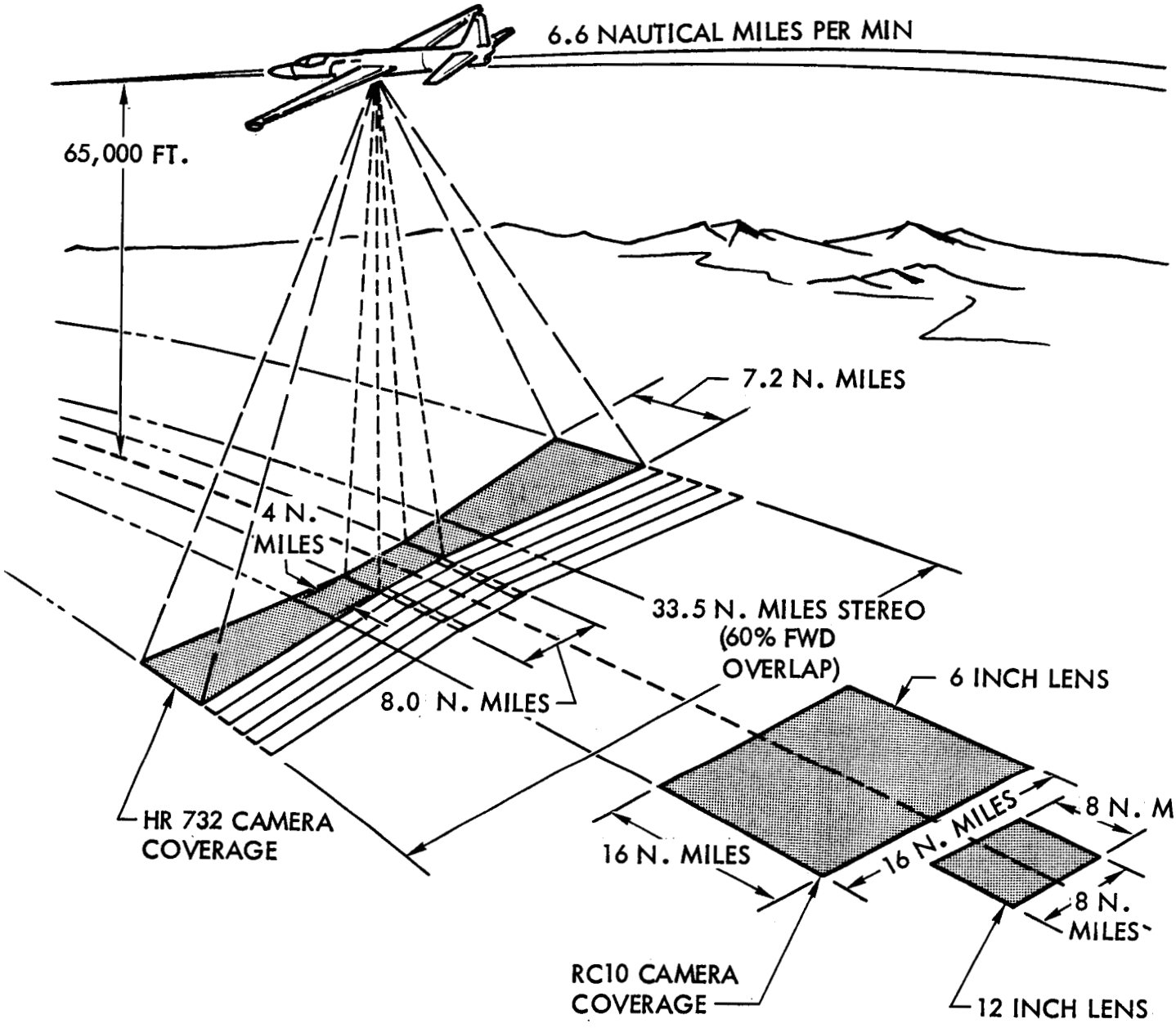


FIGURE A10 A4 CAMERA COVERAGE

DUAL RC-10 METRIC CAMERA CONFIGURATION

The dual RC-10 configuration consists of two (2) vertically mounted RC-10 cameras. The system is normally flown to provide multi-emulsion or multi-scale coverage.

Camera operation is controlled by an intervalometer which is variable from 2 to 120 seconds in 1 second intervals.

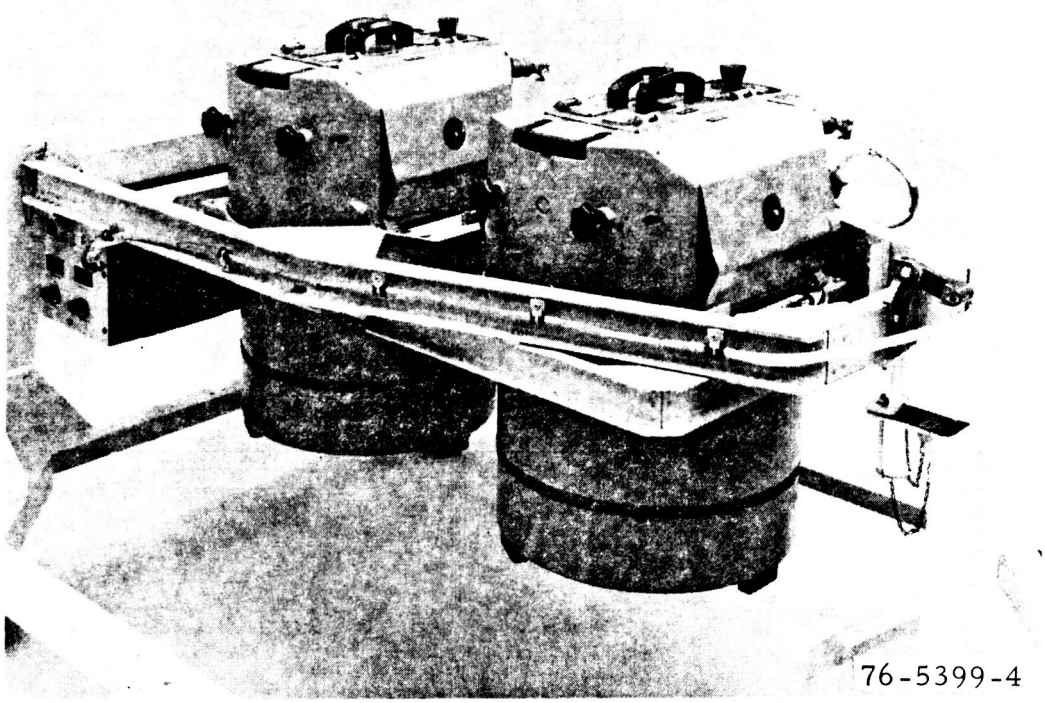
Data annotation is provided in the interframe spacing. The data is the same as that for the Vinten cameras. (See Section AI).

The dual RC-10 configuration is flown with an EAQ80 equipment bay lower hatch. (Refer to Investigators' Handbook, Volume I).

Camera specifications are:

Format size	- 9 x 9 inches
Lens	- Wild-Heerbrug Universal Aviogon II 6 inch f4, with an angular field of view of 73° 45', or an interchangeable 12 inch Aviotar II f4, with an angular field of view of 41°.
Ground coverage	- From an altitude of 65,000 ft 16 x 16 nautical miles (256 square nautical miles) for the 6 inch lens

Ground coverage (Continued)	- 8 x 8 nautical miles (64 square nautical miles) for the 12 inch lens.
Ground resolution	- From an altitude of 65,000 ft 15 to 25 ft for the 6 inch lens
	- 4 to 15 ft for the 12 inch lens



CONSISTS OF:

- TWO RC10 METRIC CAMERAS
- 6 INCH OR 12 INCH FOCAL LENGTH LENS
- 9 X 9 INCH FORMAT
- 9.5 INCH X 400 FT FILM
- INTERVALOMETER OVERLAP CONTROL - STEREO FORMAT
- CORNER AND SIDE FIDUCIAL MARKS
- FRAME ANNOTATION
- GROUND RESOLUTION
  - 6 INCH LENS 15 TO 25 FT
  - 12 INCH LENS 4 TO 15 FT

FIGURE A11 DUAL RC-10 CAMERA SYSTEM

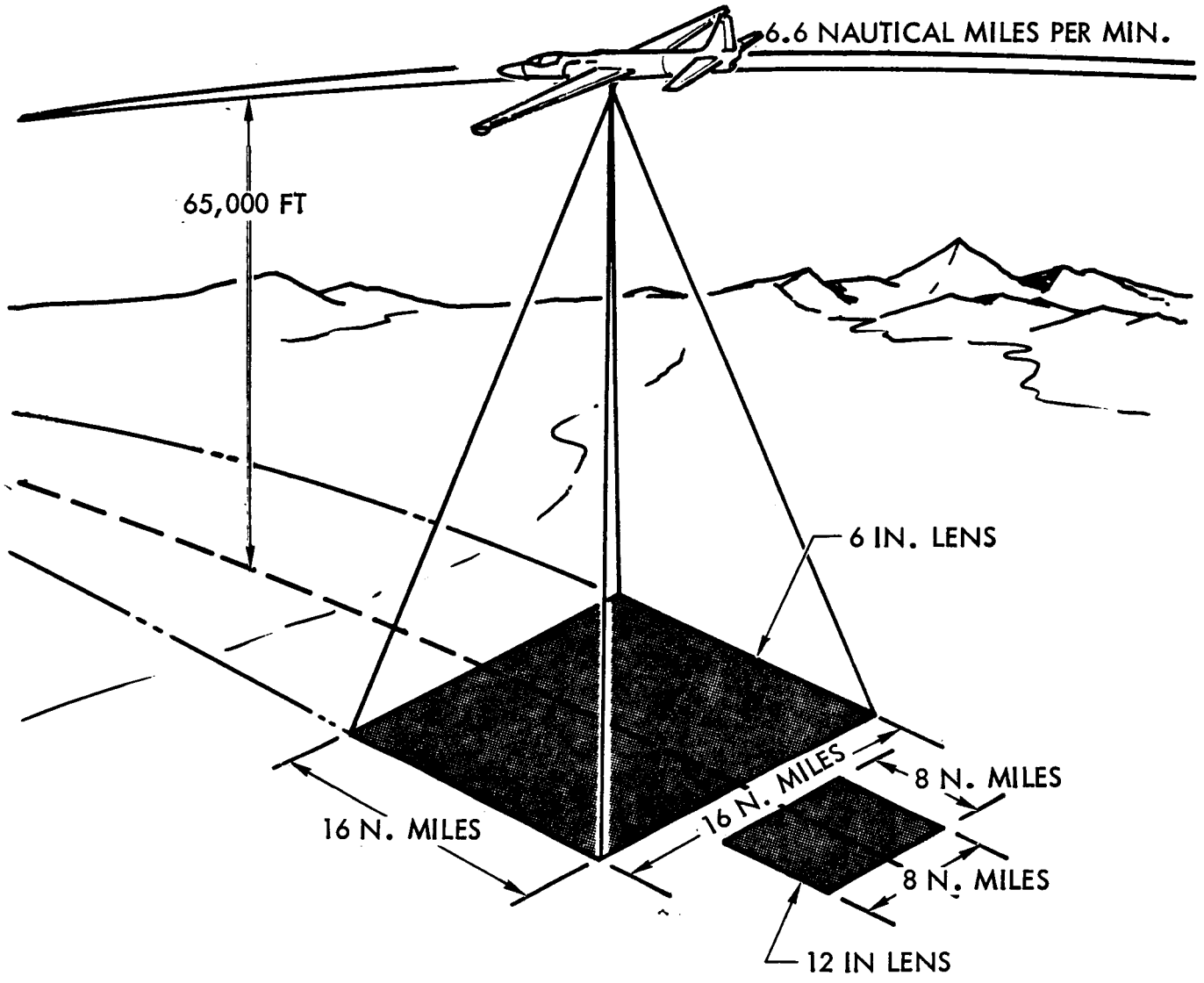


FIGURE A12 DUAL RC-10 CAMERA COVERAGE

I^2S MULTISPECTRAL CAMERA

The I^2S (International Imaging Systems) camera consists of a single camera body and four (4) separate lenses to provide for multi-spectral coverage. All lenses image on the same film emulsion, eliminating the chance of roll-to-roll processing variation. The normal filtration flown in the I^2S camera is as follows:

Lens	Filtration	Bandpass
1	49 B + IR Cutoff	400-470 nanometers
2	57 + IR Cutoff	470-590 nanometers
3	25 + IR Cutoff	590-690 nanometers
4	88A	740-900 nanometers

Other film/filter combinations are available by arrangement with AIRP.

Data annotation is provided by 15 digits of data on frame 3 of the format. The data presentation is the same as that for the Vinten cameras. (See Section AI).

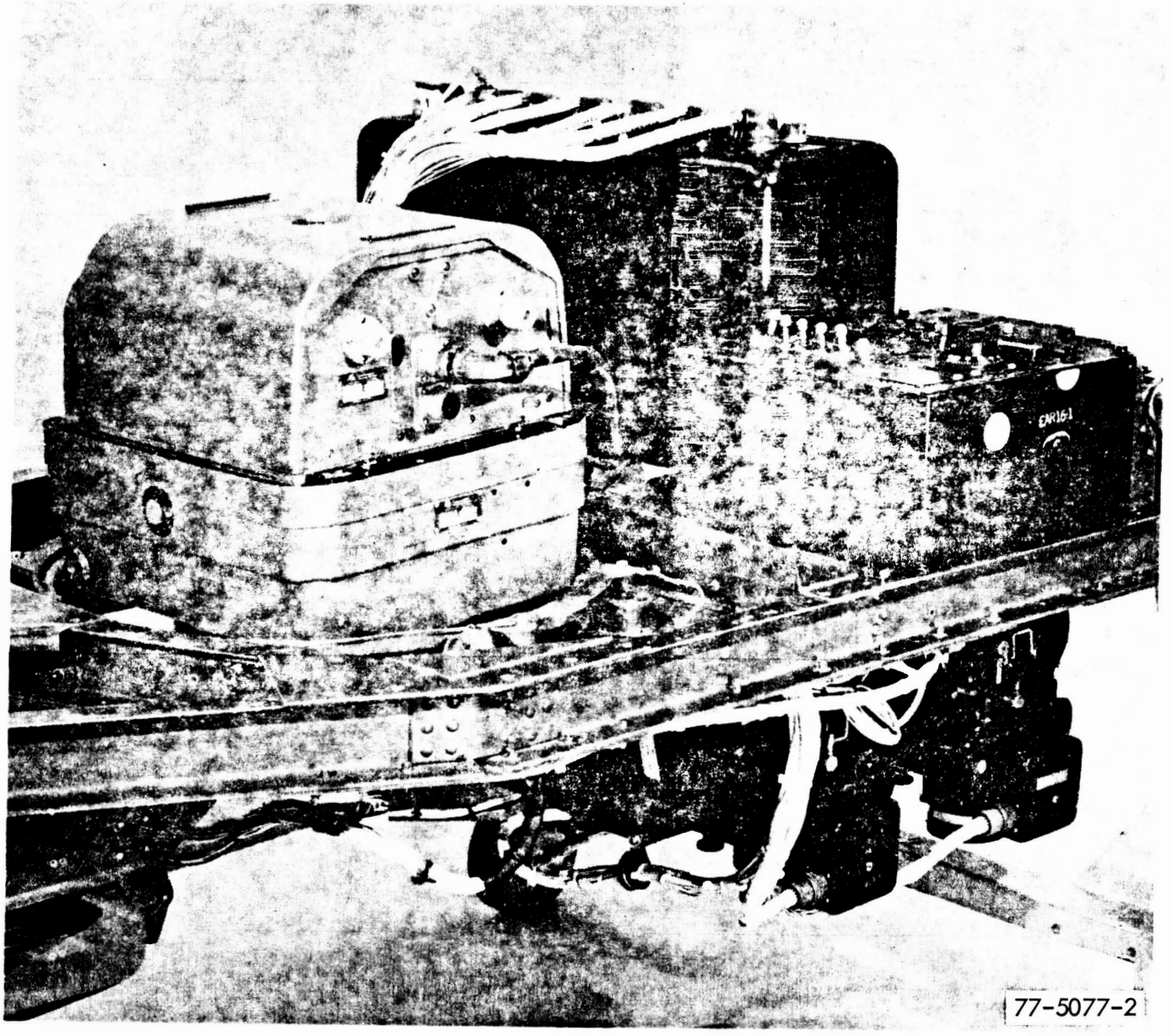
Camera operation is controlled by an intervalometer which is variable from 2 to 120 seconds in 1 second intervals.

The I^2S camera is flown with an F921 equipment bay lower hatch. (Refer to Investigators' Handbook, Volume I).

Camera specifications are:

Format size - Four 3-1/2 x 3-1/2 inch images on 9 x 9 inch format

Lens	- Four integrated 3.94 inch f3.8, with an angular field of view of 47^{o}.
Ground coverage	- From an altitude of 65,000 ft 9.5 x 9.5 nautical miles (89.75 square nautical miles).
Ground resolution	- From an altitude of 65,000 ft 20 to 30 ft



CONSISTS OF:

- 1^2S CAMERA WITH FOUR (4) 3.94 INCH FOCAL LENGTH LENSES
- FORMAT - FOUR (4) 3 1/2 X 3 1/2 INCH IMAGES ON 9 X 9 INCH FILM
- 9.5 INCH X 250 FT FILM
- INTERVALOMETER OVERLAP CONTROL
- FRAME ANNOTATION
- GROUND RESOLUTION - 20 TO 30 FT

FIGURE A13 1^2S CAMERA SYSTEM

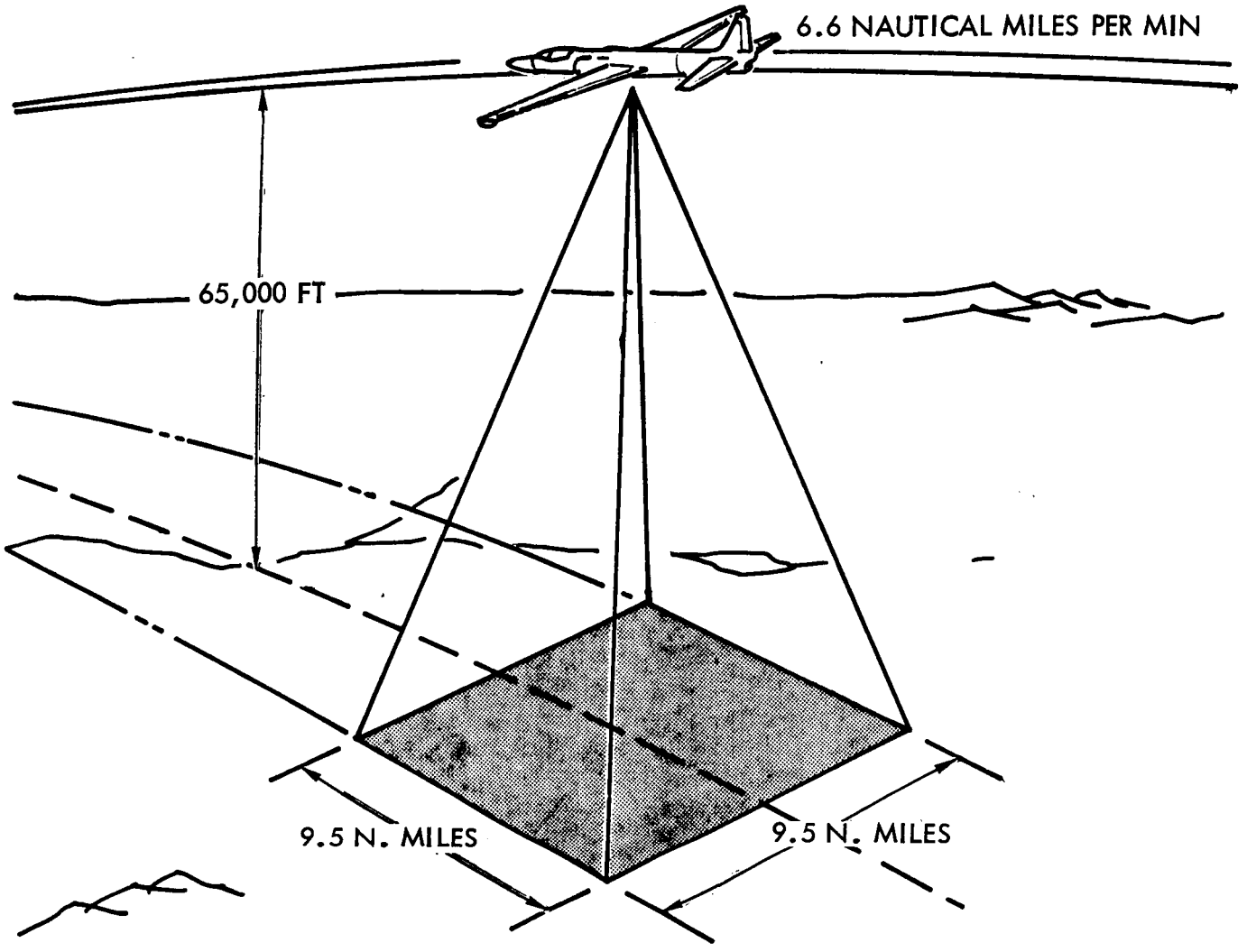


FIGURE A14 1^2S CAMERA COVERAGE

B CAMERA

The B camera is a high resolution, 36 inch focal length camera system designed to provide large scale photography over a large area. The camera images onto two (2) 9-1/2 inch wide frames of film through a single lens, producing an 18 x 18 inch exposure.

To provide horizon-to-horizon coverage, the lens indexes through 7 positions; nadir, 3 left oblique and 3 right oblique.

Camera operation is mechanically programmed to provide 50 to 70 percent overlap. The normal operational film loads of the camera is 700 feet or approximately 400 exposures.

The five available modes of operation are as follows:

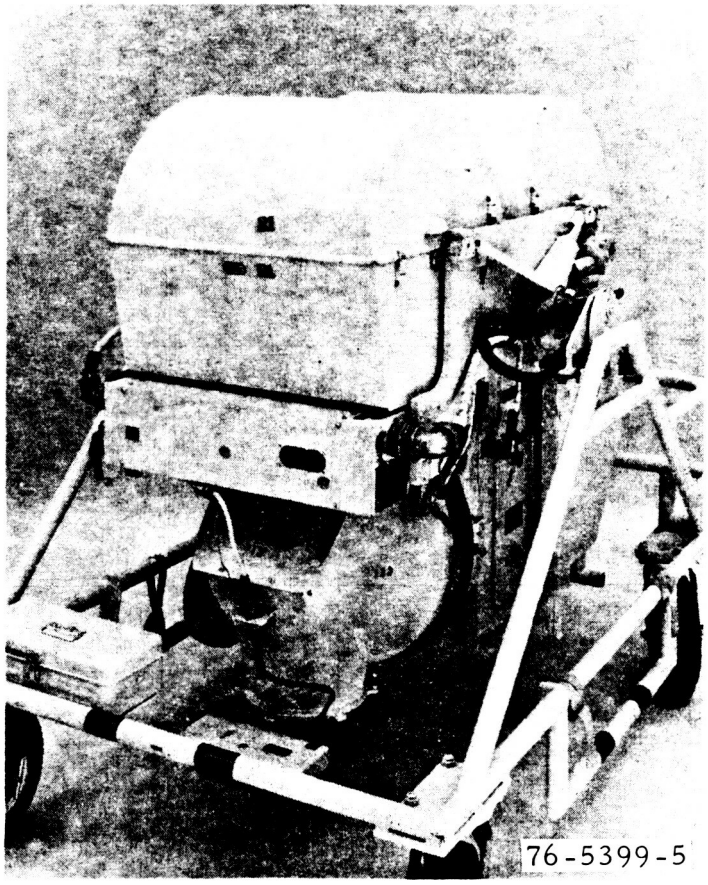
Mode 1	All seven positions
Mode 2	Nadir, 24° 30' left and right oblique
Mode 3	Nadir, 24° 30', 49°, 73° 30' right oblique
Mode 4	Nadir, 24° 30', 49°, 73° 30' left oblique
Mode 5	Nadir, 24° 30', 49° left and right oblique

Film annotation includes frame number, time and oblique position.

The B camera is flown with an F210 equipment bay lower hatch. (Refer to Investigators' Handbook, Volume I).

Camera specifications are:

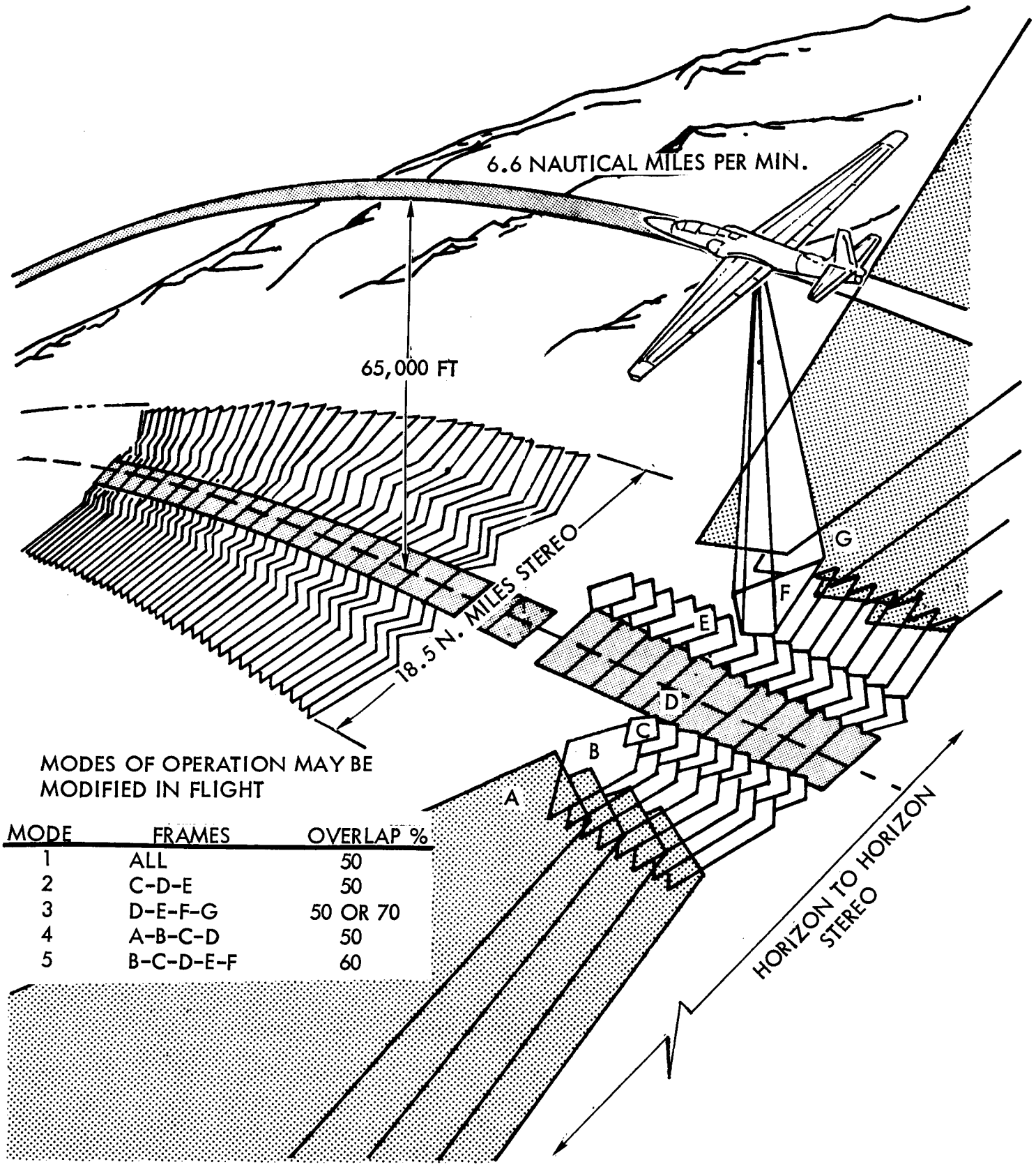
Format size	- 18 x 18 inches
Lens	- HR73B1 36 inch f10, with an angular field of view of 28°.
Ground coverage	- From an altitude of 65,000 ft depending on the operating mode, horizon to horizon in Mode 1 and 18.5 nautical miles in Mode 5.
Ground resolution	- From an altitude of 65,000 ft 2.5 ft



CONSISTS OF:

- 36 INCH FOCAL LENGTH
- 18 X 18 INCH FORMAT
- 9.5 INCH X 600 FT FILM
- 50% OVERLAP - STEREO
- AUTOMATIC OPTICAL IMC
- GROUND RESOLUTION 2.5 FT
- ANNOTATION

FIGURE A15 B CAMERA



MODES OF OPERATION MAY BE MODIFIED IN FLIGHT

MODE	FRAMES	OVERLAP %
1	ALL	50
2	C-D-E	50
3	D-E-F-G	50 OR 70
4	A-B-C-D	50
5	B-C-D-E-F	60

FIGURE A16 B CAMERA COVERAGE

OPTICAL BAR CAMERA

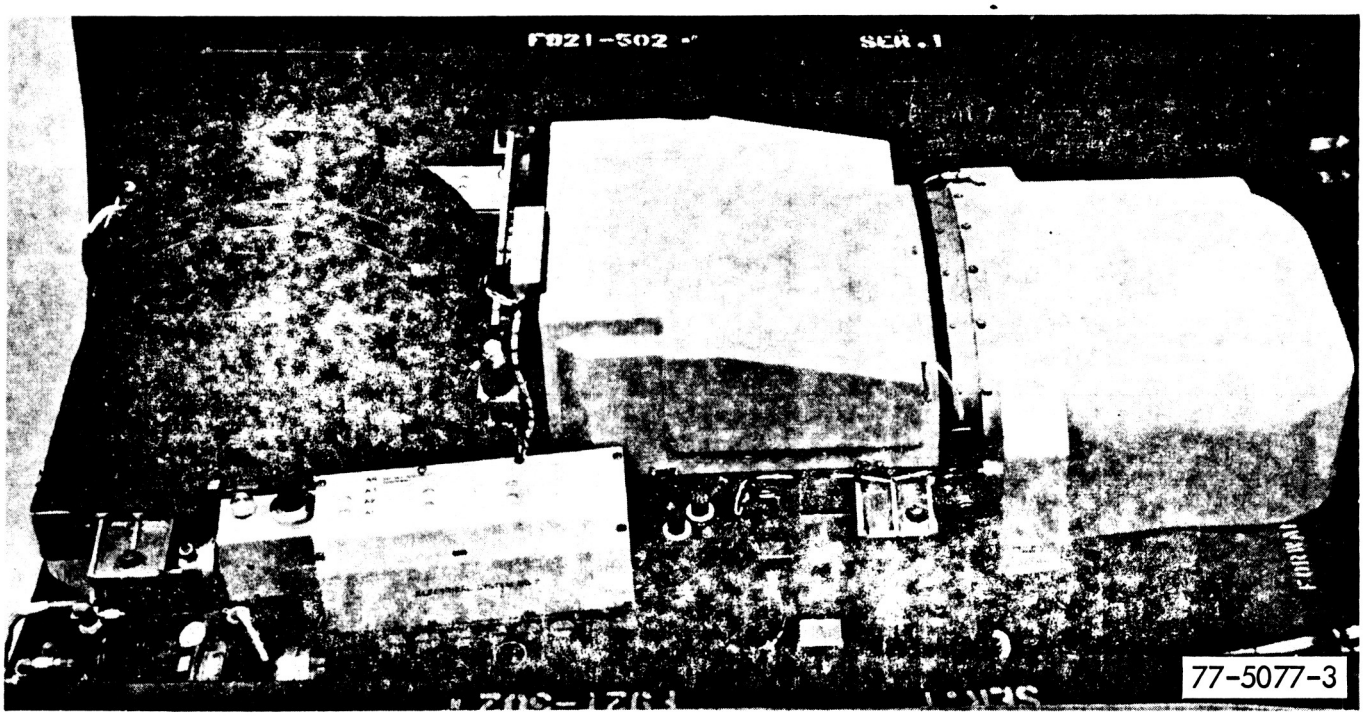
The Itek Optical Bar camera is a high resolution panoramic camera with a 24 inch focal length lens which sweeps across a 120° field of view. The format size is 4-1/2 by 50 inches. The magazine is capable of holding up to 6500 feet of film.

Film annotation includes time frame count, lens serial number and focal length.

The Optical Bar camera is flown with a F921 equipment bay lower hatch. (Refer to Investigator's Handbook, Volume I).

Camera specifications are:

Format size	- 4.5 x 50 inches
Lens	- Itek KA-80A 24 inch f3.5 with an angular field of view of 120°.
Ground coverage	- From an altitude of 65,000 ft, 85 square miles
Ground resolution	- From an altitude of 65,000 ft 2 ft



CONSISTS OF:

- ITEK OPTICAL BAR CAMERA WITH KA-80A 24 INCH FOCAL LENGTH LENS
- 4.5 INCH X 50 INCH FORMAT
- 5 INCH X 6500 FT FILM
- FRAME ANNOTATION (SEE CAMERA DESCRIPTION)
- GROUND RESOLUTION - 2 FT

FIGURE A17 OPTICAL BAR CAMERA

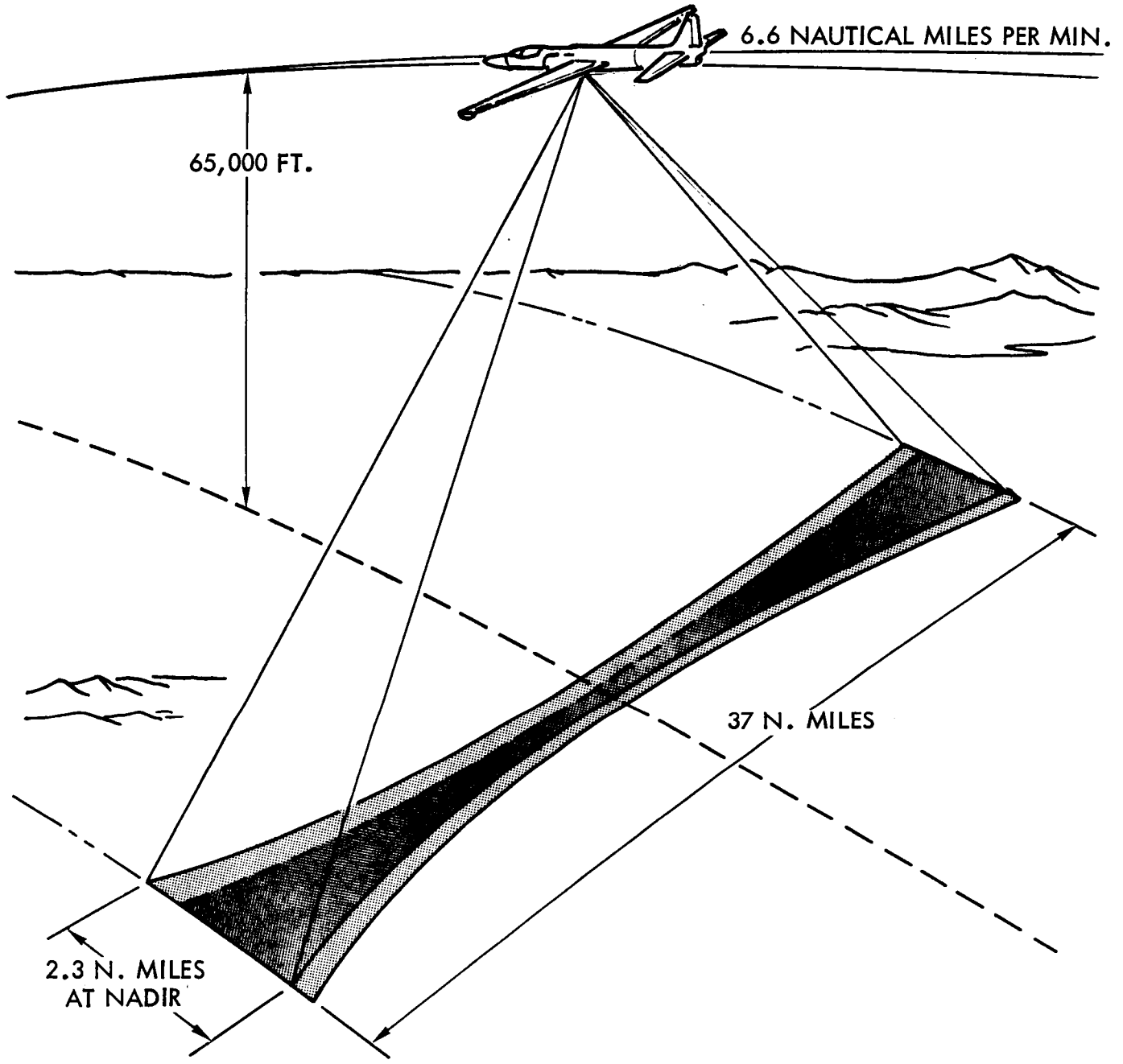


FIGURE A18 OPTICAL BAR CAMERA COVERAGE

EXPERIMENT TRACKER CAMERAS

INTRODUCTION

For some experiment installations, it is desirable to include a "tracker camera" to provide photography to assist in the reduction of data gathered by a given experiment.

For this capability, the program maintains several types of tracker camera systems that may be considered in the planning of an experiment configuration.

It should be noted, that while the Project will maintain and provide the camera system, it is the responsibility of the user to provide the necessary funding to integrate the camera into his configuration. Further, AIRP will provide and process all films and provide the experimentor with a reasonable number of copies of the photography; however, the original transparency negative remains the property of AIRP.

VINTEN CAMERA (TRACKER INSTALLATION)

A Vinten Camera tracker is operational at this time for the Ocean Color Scanner as shown in Figure A19. It consists of the Vinten Multi-Spectral Camera System (4 cameras) as described in Section AI and the Ocean Color Scanner described in Section CI of this handbook.

With data gathered by this installation, the experimentor is able to compare an actual photograph with the data obtained over the same ground track. This comparison can assist in the data interpretation, data enhancement and provide a means for possible system improvement modifications.

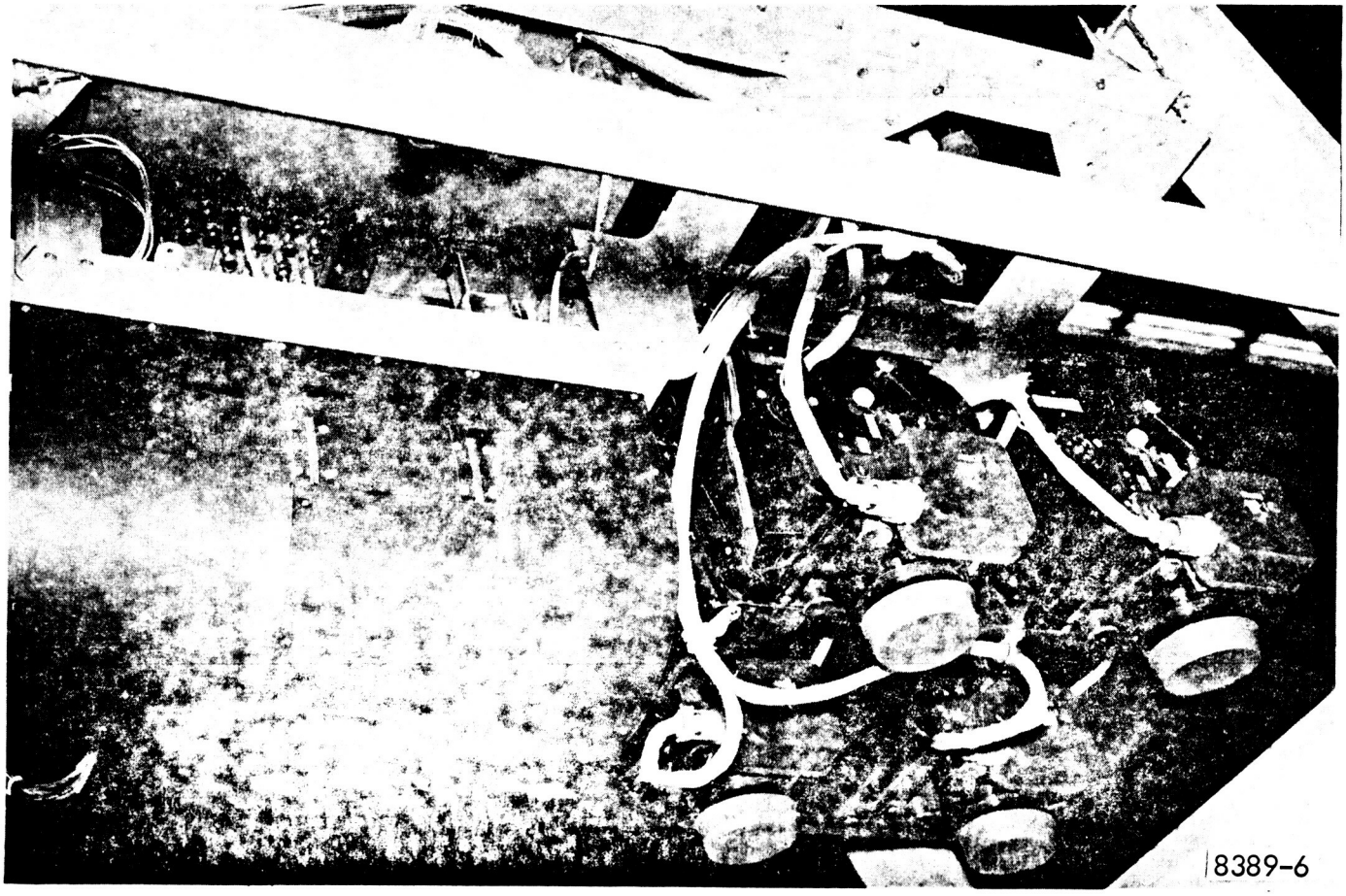


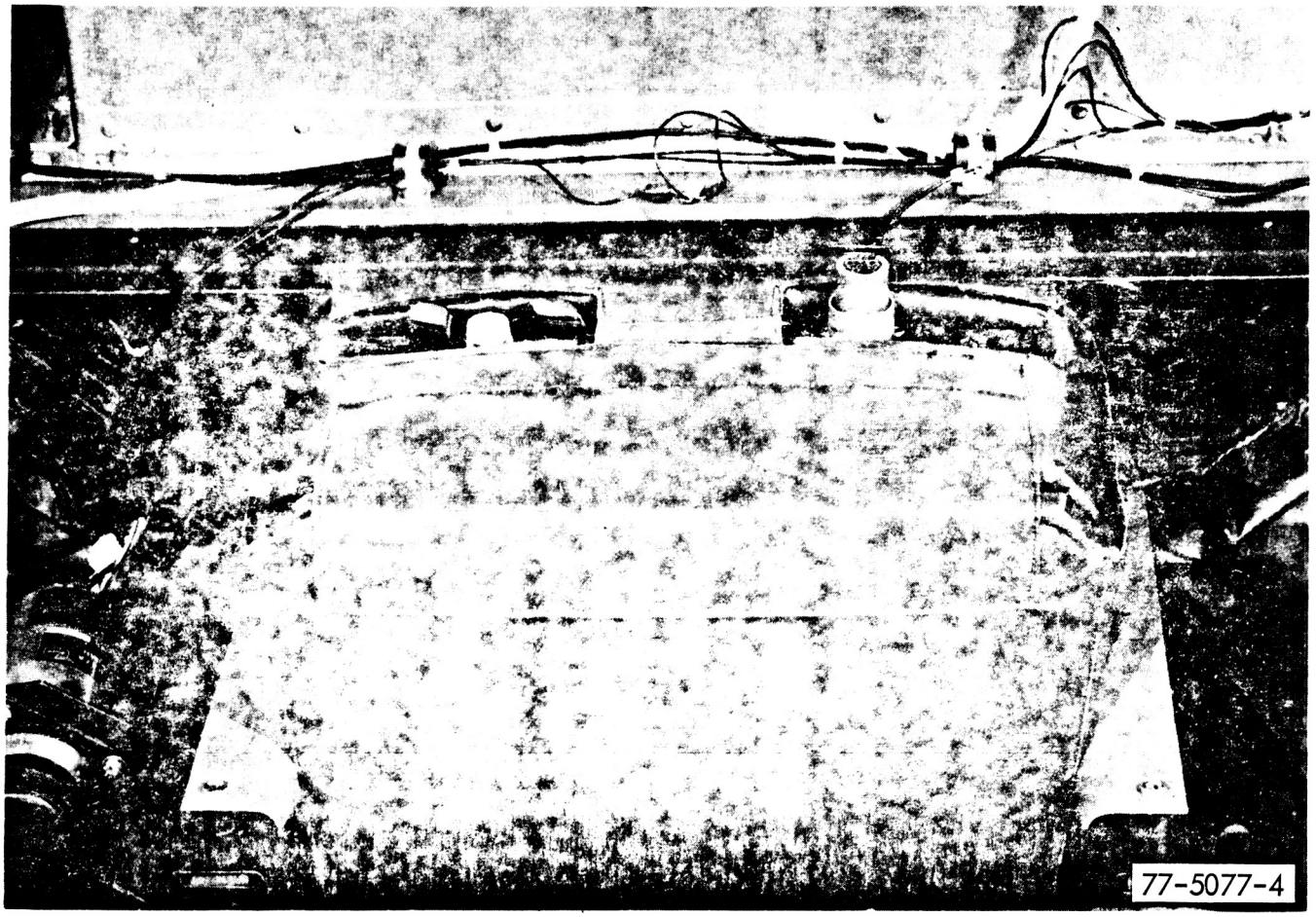
FIGURE A19 VINTEN CAMERA - TRACKER INSTALLATION

HP 307 PANORAMIC CAMERA (TRACKER MODIFICATION)

This tracker camera has previously been integrated with an operational IR scanning device as shown in Figure A20.

The camera was fitted with a remote intervalometer, mounted adjacent to the camera, which can be adjusted to provide various percentages of photo overlap. The camera was vertically positioned to view through an existing hatch photographic window.

The use of the photographic data permitted the investigator to correlate specific ground targets with IR recorded data and in this manner, erratic data excursion caused by sun glints from water or heat reflective surfaces such as metallic structures were readily identified.



CONSISTS OF:

- HYCON HP-307 PANORAMIC CAMERA
- 80mm FOCAL LENGTH LENS
- 2 1/4 X 7.2 INCH FORMAT
- 70mm X 100 FT FILM
- INTERVALOMETER OVERLAP CONTROL

FIGURE A20 HP307 PANORAMIC TRACKER CAMERA

T-35 TRACKER CAMERA INSTALLATION

Several of the Q-Bay lower hatches in the program such as the F210 and 75F177 (as shown in Volume 1) are equipped to accept the installation of the T-35 Tracker Camera for data correlation.

The camera is shown in Figure A21.

For use of this camera, the experimentor is cautioned to check in advance, through the U-2 Project Office, to assure compatibility of the camera installation with the specific hatch configuration being considered for the experiment. Camera availability should also be coordinated.

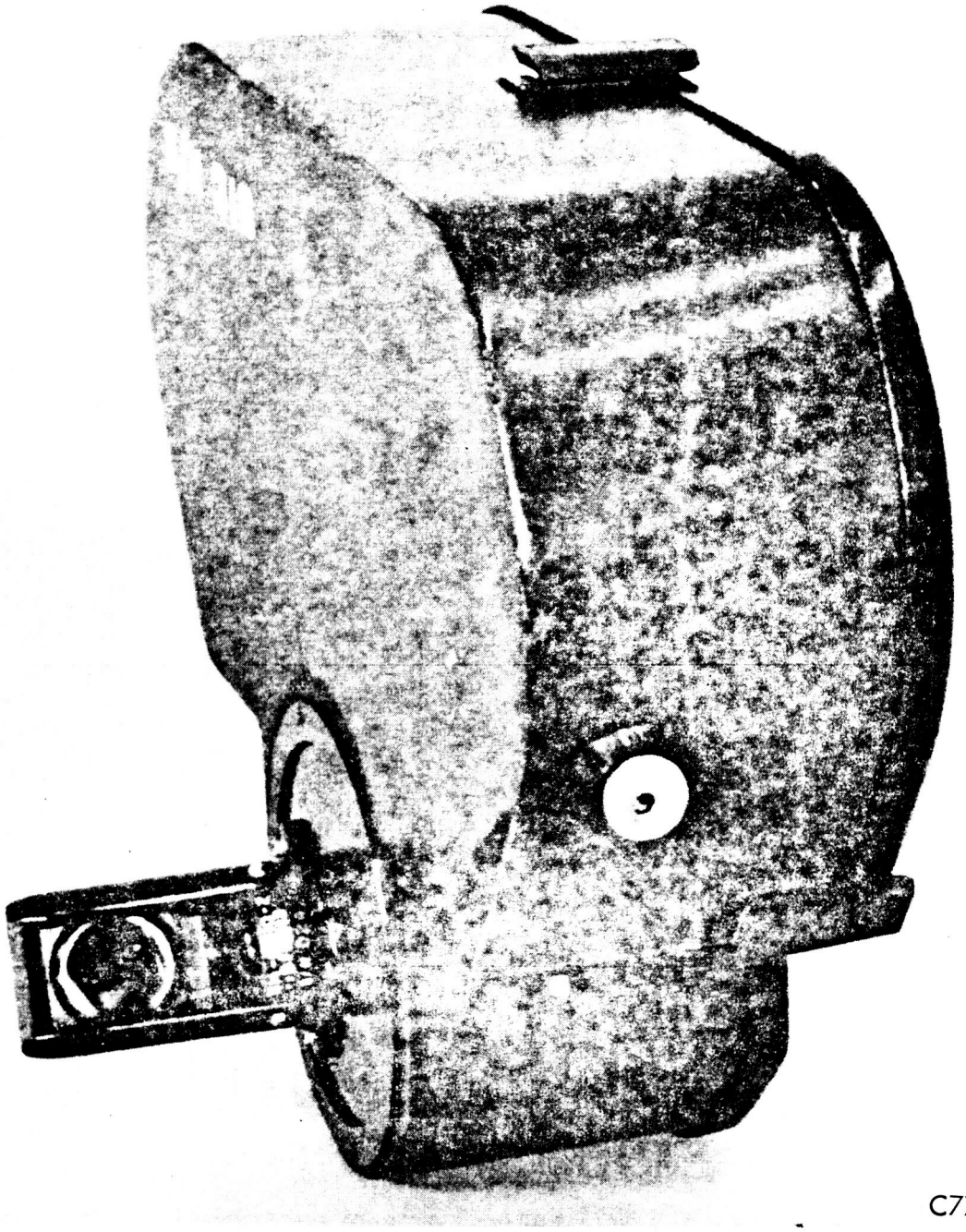


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FIGURE A21 T-35 TRACKER CAMERA

ASTRONOMY AND ATMOSPHERIC SENSORS

INTRODUCTION

There are many non-camera sensors currently in an operational status in the program at this time. As new systems are developed and become operational, their descriptions will be added to this section of the handbook.

It should be noted that all of the systems in this section except the F-2 filter sampler are the property of other government agencies or individual experimentors and as such are not normally available for use by other investigators. Sensor descriptions are included in this handbook to illustrate the wide variety of sensors operating on the U-2 and to indicate to interested scientists the type of instrumentation which has operated in the past on the U-2 aircraft. This information may assist future investigators in developing an aircraft integration design for their own sensors.

AETHER DRIFT

The experiment consists of two upward-looking microwave radiometers. The primary goal of the Aether Drift experiment is the measurement of the proper motion of the solar system with respect to the distant matter in the universe. This can be done by measuring the motion of the earth through the universal $3^{\circ}K$ black body background radiation. Direction of anistropies of the $3^{\circ}K$ cosmic background radiation will show the motion of the earth with respect to the distant matter of the universe - the "Aether Drift." The instrument is then designed to make a sensitive measurement of the temperature difference of the primordial $3^{\circ}K$ black body background radiation between pairs of directions in the sky.

The apparatus for the Aether Drift experiment is mounted in a Q-Bay upper hatch assembly which has been modified to accept rotating experiment devices. A more detailed description of the hatch is given in Section DIII - Special Equipment Configurations.

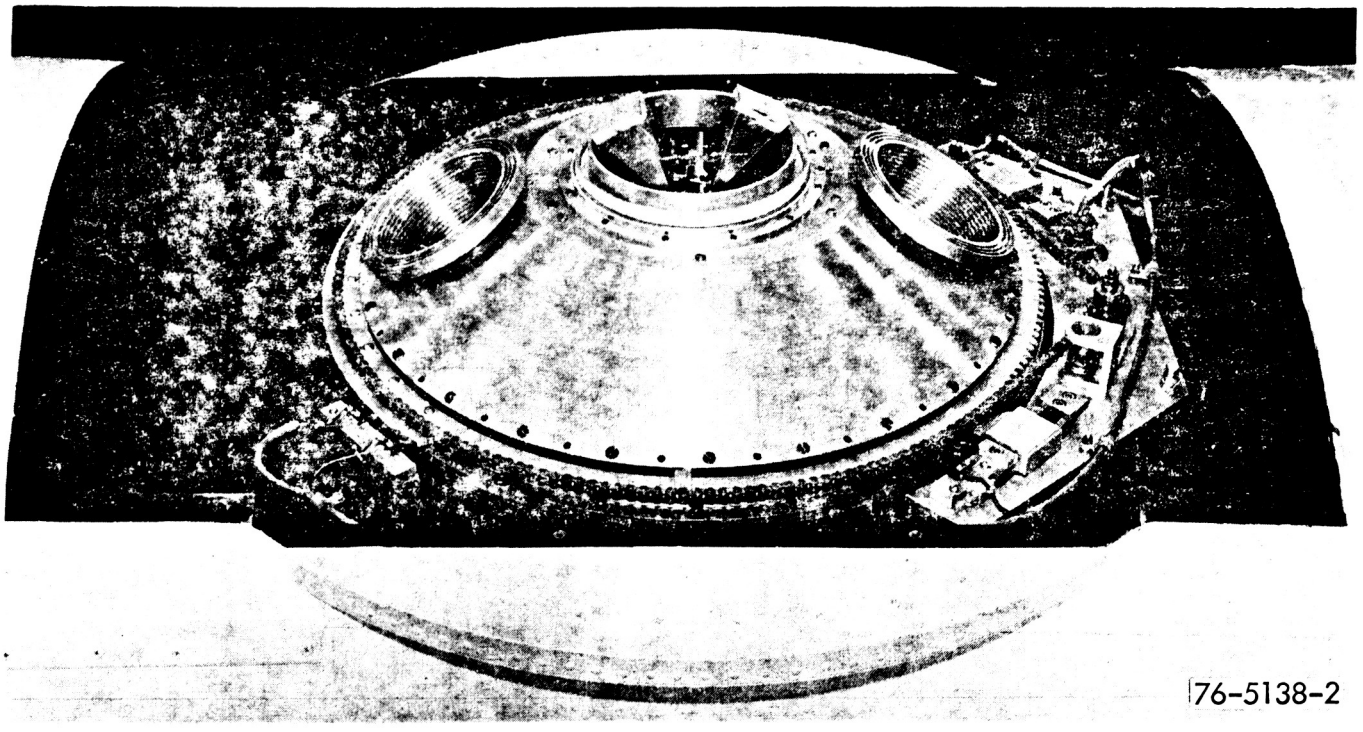
Two (2) radiometers are supported and contained within this special hatch. Each radiometer has two horn antennas that are separated in direction by 60° with an angular resolution of about 10°, and point symmetrically about the zenith direction to the left and right of the center line of the plane. The 33.6 GH_z radiometer measures the antistropy of the microwave background radiation. The 54.0 GH_z radiometer measures the contribution of the atmospheric microwave emission to the 33.6 GH_z signal. The 33.6 GH_z horns look through open ports in the upper hatch.

The Q-Bay and cabin pressure is preserved by a pressure can that is supported by the hatch and encloses the radiometers and the bulk of the

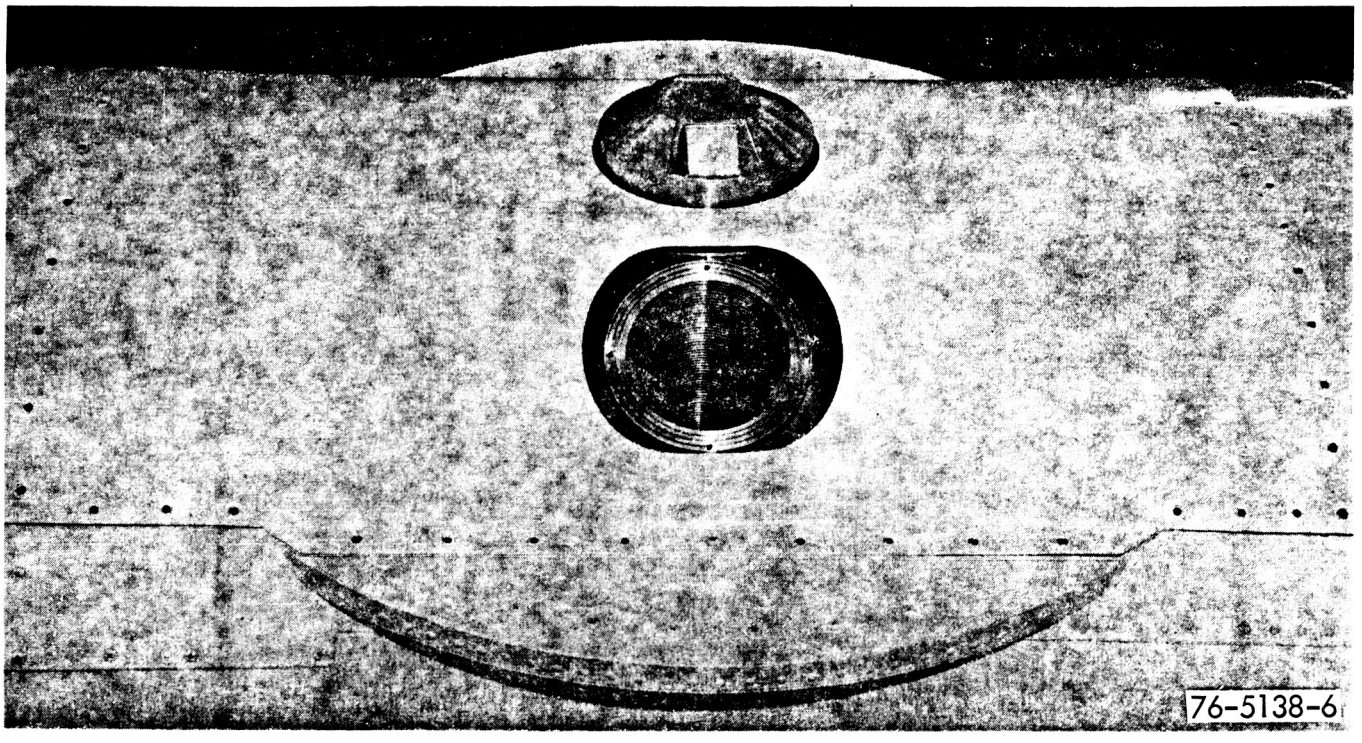
electronics. The 33.5 GHz horns look through open ports in the upper hatch. The position of the antennas are interchanged periodically every 64 seconds by a rotation system which drives the bearing that supports the equipment in the pressure can.

Data is recorded on a digital tape recorder mounted externally to the pressure can. The pilot has three controls; power on/off, recorder on/off, and antennas store/operate.

Principal Investigators: Dr. Richard A. Muller
Dr. George F. Smoot
Mr. Marc V. Gorenstein
Lawrence Berkeley Laboratory
Berkeley, California 94720



WITHOUT AIRPLANE FAIRING



WITH FAIRING INSTALLED

FIGURE B1 AETHER DRIFT EXPERIMENT

SOLAR ENERGY MONITOR IN SPACE (SEMIS)

This system has 3 objectives: 1) to measure the solar constant with an accuracy better than 0.5%; 2) to measure the solar spectral irradiance with an accuracy between 1% and 5% in the range of 300 nanometers to 2600 nanometers; and 3) to determine the variability of these parameters with a precision greater than the state-of-the-art absolute accuracy. This sensor was first flown in October 1976, and normally is flown as a piggyback sensor.

The SEMIS instrument is a small sensor weighing about 30 lb. It is mounted directly to the aircraft upper hatch and uses a small six inch diameter quartz window. Both NASA U-2 aircraft upper hatches have this quartz window installed.

The Solar Energy Monitor in Space (SEMIS) consists of a spectroradiometer for measuring solar spectral irradiance and a broadband, thermal radiometer for measuring total solar irradiance. The spectroradiometer utilizes a miniature prism monochromator and two sensors: an MOS photodiode and a PbS infrared detector. This combination enables measurements to be made over the entire 300 to 2500nm wavelength region. A 600 H_Z tuning fork type chopper modulates the monochromatic flux at the exit slit of the monochromater such that the MOS detector is irradiated during half the cycle and the PbS is irradiated during the second half. The preamplifiers provide differential outputs for amplifications and detection of later stages. The thermal detector consists of a wirewound thermopile and measures the total irradiance incident on the detector.

Calibration of the system is based on the NBS standards of total and spectral irradiance. All the data is recorded on a digital cassette recorder.

Principal Investigator: Mr. Donald Williams
NASA/GSFC
Greenbelt, Maryland

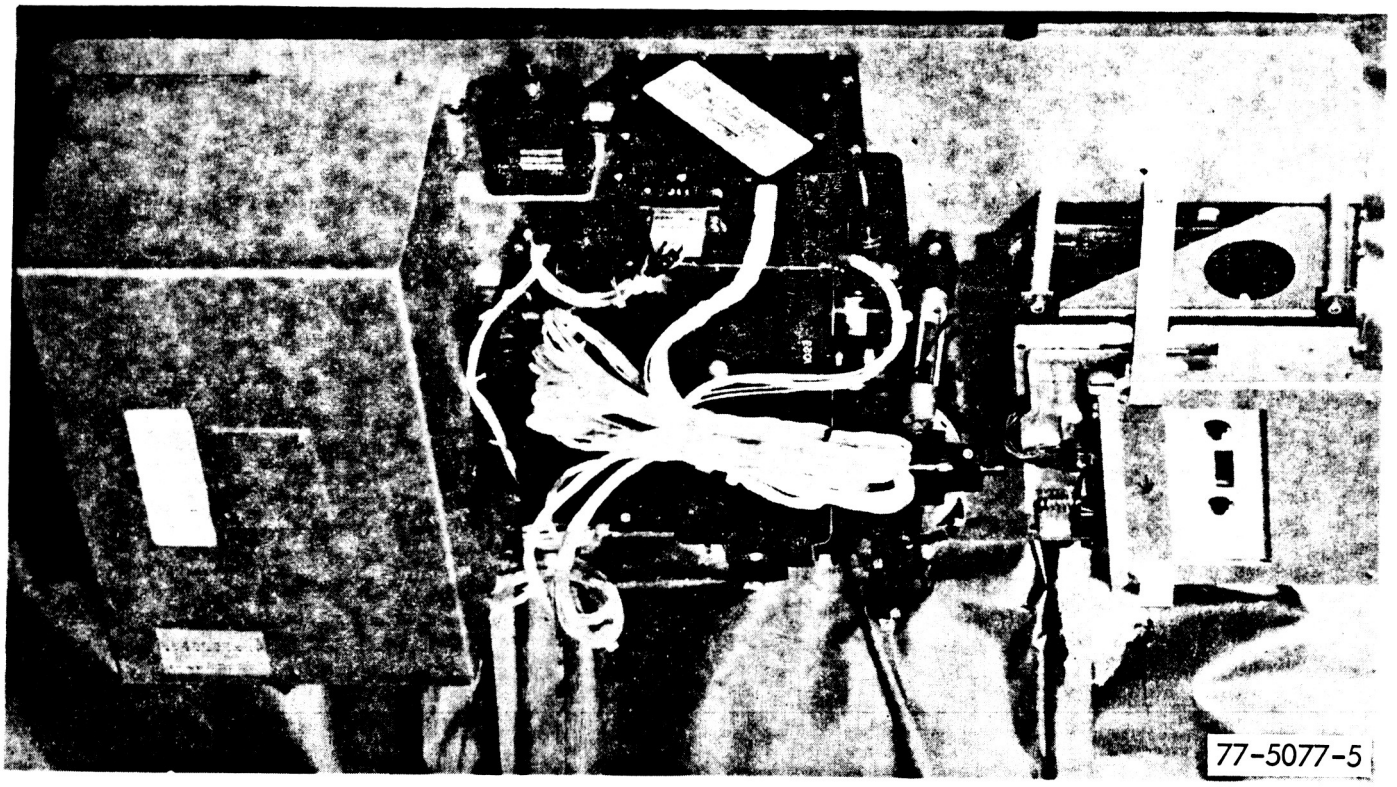


FIGURE B2 SEMIS EXPERIMENT (VIEW LOOKING UP)

CO_2 COLLECTOR

The CO_2 Collector is a small piggyback sensor designed to collect radioactive carbon dioxide in the stratosphere. The objective of this research is to use the radiocarbon as a tracer in atmospheric exchange and climate studies. Since the early 1950's, artificial radiocarbon has found its way into the stratosphere mainly due to testing of nuclear devices. This radiocarbon is oxidized to $^{14}CO_2$, which mixes with inert CO_2 and its life cycle throughout the atmosphere can thus be traced.

The sensor consists of an air scoop and a collection bottle. This bottle is a cylinder approximately 36 cm by 14 cm in diameter which is filled with a molecular sieve composed of synthetic zeolite, a mineral substance capable of absorbing carbon dioxide. The unit itself is mounted piggyback in the top aft fuselage area (canoe).

When the aircraft reaches the desired altitude (normally 60,000 ft), the pilot opens the access valve by remote control. Air now flows through the collector and after a normal exposure time of 3 hours, the valve is closed. Typically, about 1 to 2 liters of CO_2 is collected during a flight. The collection cylinder is then removed from the aircraft and sent to the Isotope Laboratory at UCLA for analysis.

Principal Investigator: Dr. Rainer Berger
University of California
Los Angeles, California

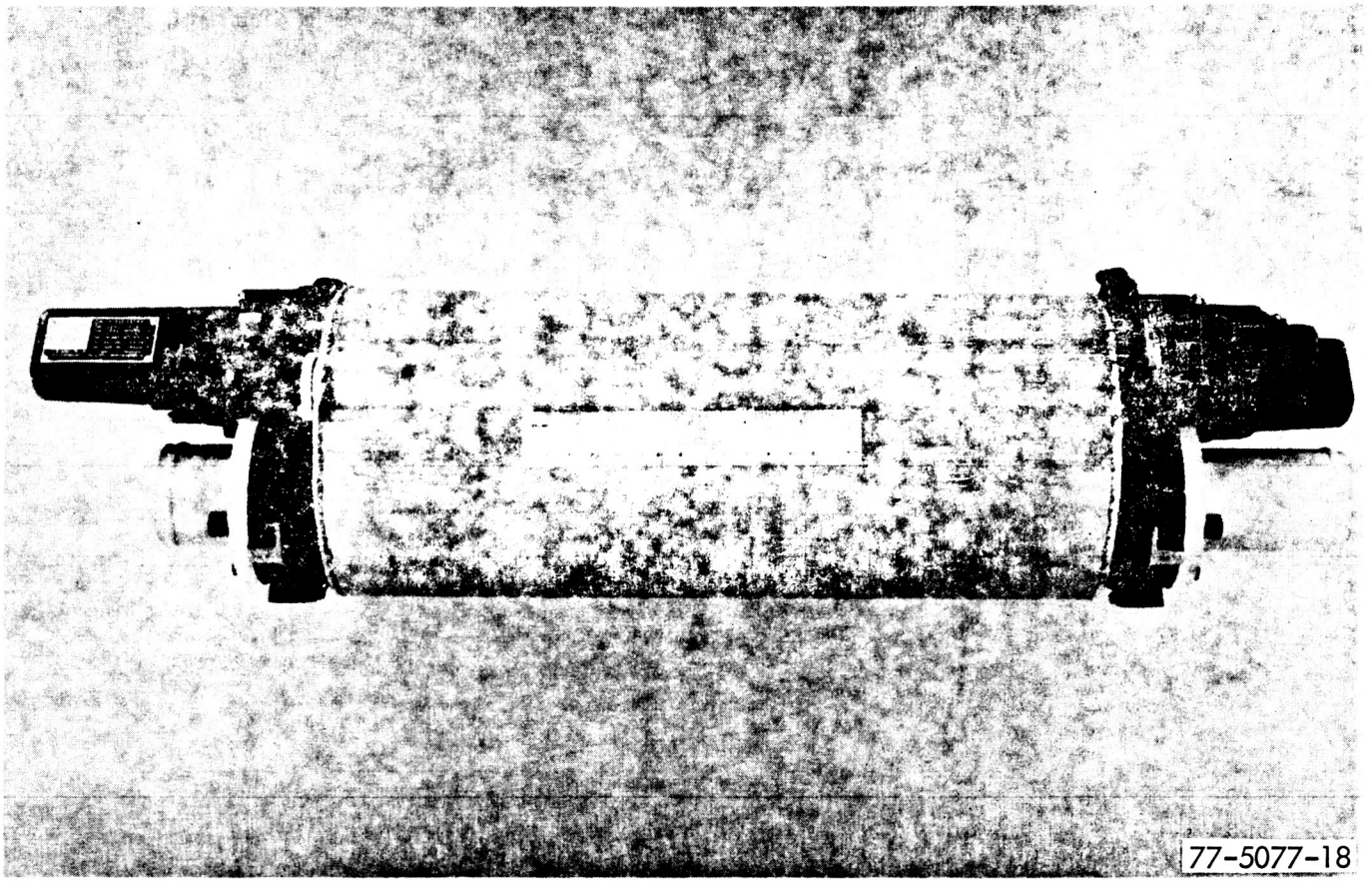


FIGURE B3 CO_2 COLLECTOR

WATER VAPOR RADIOMETER
(WVR)

The WVR is a small upward looking sensor designed to determine the total water vapor overburden above the aircraft. The WVR can also be reconfigured to view horizontally. The data is useful in studies of the impact of the SST aircraft, atmospheric physics and astronomy programs. Similar instrumentation is flown onboard the NASA Convair 990 and C141 astronomical observatory. The purpose of this research is the determination of stratospheric water vapor mass and its variability.

This sensor is a piggyback instrument with a small radiometer weighing about 10 lbs. The radiometer itself is installed in the canoe (top, aft fuselage portion of the aircraft) and the tape recorder and radiation bolometer are mounted in the upper Q-Bay on a special rack. The WVR has a 2 degree instantaneous field of view (IFOV) and utilizes a deuterated Tri-Glycerine Surfate (DTGS) detector to measure emissions in the water vapor infra-red spectral bands between 18 and 35 microns.

The data can be sampled every 10 seconds, 60 seconds or 10 minutes and is recorded in digital format on magnetic tape for subsequent analysis.

Principal Investigator: Dr. Peter M. Kuhn
Atmospheric Physics and Chemistry Laboratory
National Oceaic & Atmospheric Adm. (NOAA)
Boulder, Colorado

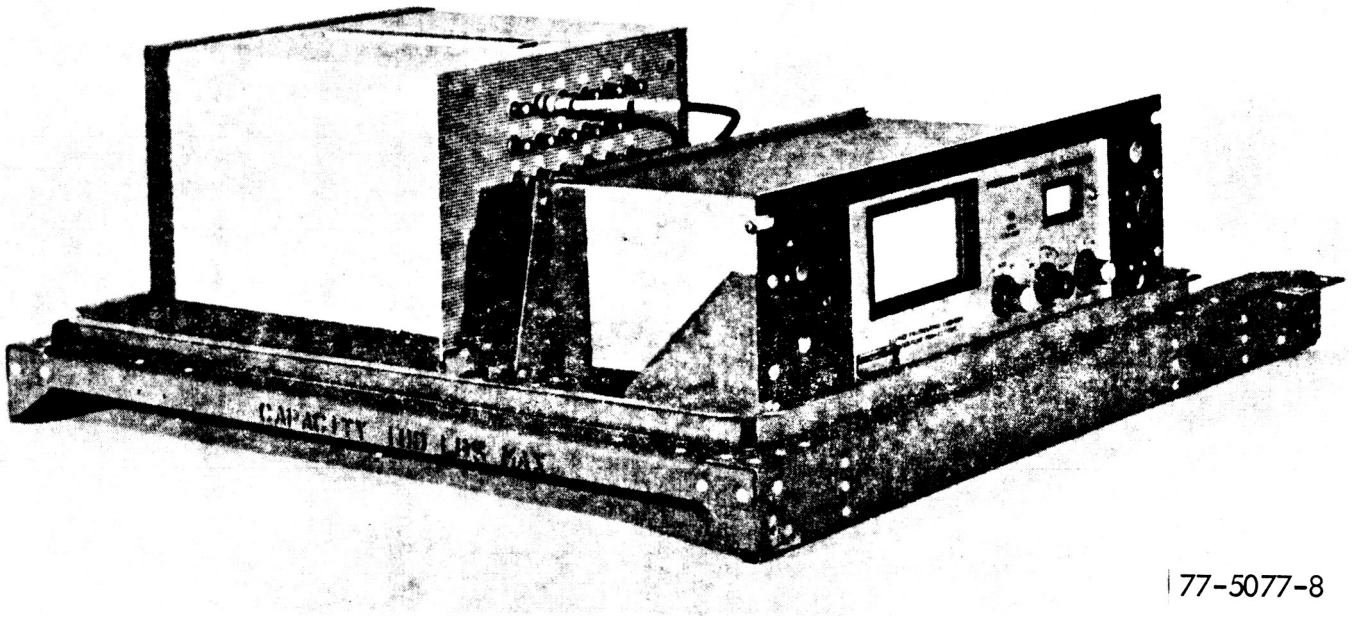


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FIGURE B4 WATER VAPOR RADIOMETER

INFRA-RED SPECTROMETER
(FLO)

FLO is a wing pod mounted infra-red spectral radiometer designed to investigate minor atmospheric constituents and their concentrations in the atmosphere. The system is currently configured to scan from 3 to 6 microns and from 6 to 12 microns. The longer wavelength region contains atmospheric emission features due to CH_4, N_2O, O_3 and HNO_3. The system can be flown simultaneously with selected lower equipment bay sensors like the SCS or SAS II. Different measurement techniques can then be used to obtain data on the same constituents.

The radiometer, developed and operated by the University of Denver, looks out of the right wing pod at an angle of 10° above the horizon. The field of view is 1° vertical and 4° horizontal. The scan time is 40 seconds.

Molecular radiaton from the atmosphere enters through a zinc selenide window and is scanned by a liquid helium-cooled grating spectrometer. The liquid helium hold time is about 20 hours. The two detectors are both copper-doped germanium.

Total sampling time is limited to about 5.5 hours by the tape supply on the digital tape recorder. This system in a different configuration has also flown on balloons.

Principal Investigators: Dr. David Murcray
Mr. Boyd Barker
University of Denver
Boulder, Colorado

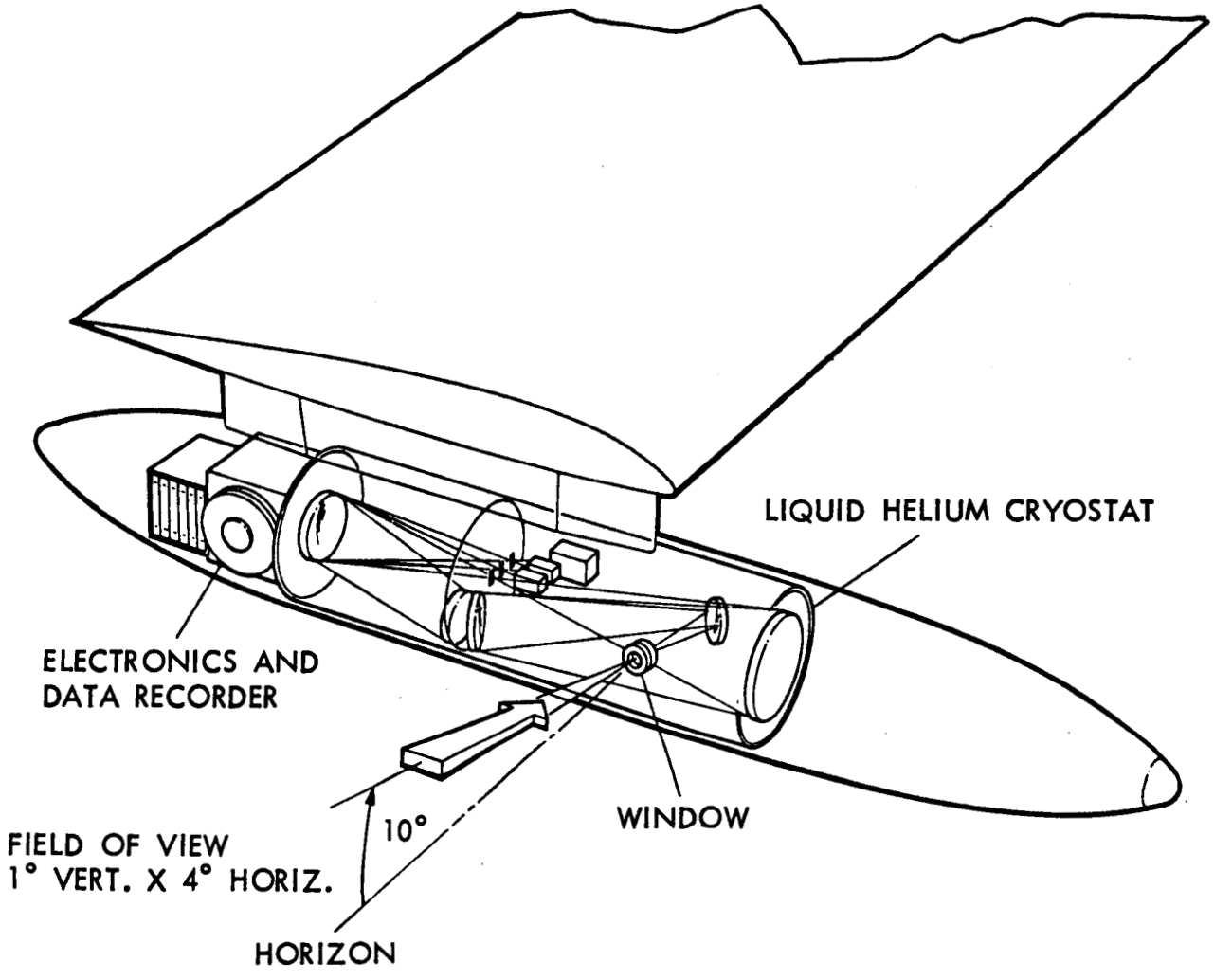


FIGURE B5 IR SPECTROMETER

RESONANCE FLUORESCENCE EXPERIMENT (REFLEX)

The REFLEX system was designed to measure data on chlorine molecules in the stratosphere. This data relates to the hypothesis that the release of fluorochlorocarbons into the stratosphere may result in the catalytic decomposition of the earth's ozone layer.

The instrument itself is a small sensor which can be mounted inside a U-2 wing pod under the aircraft wing. It consists of a special (resonance) light source and a photomultiplier, both of which are fitted with flowing O_2 filters (UV 1188 angstroms). Each is positioned to view downward into the stratosphere through a closed window in the tank. The viewing angle for each is a 60° cone. The cones intersect each other 3 inches below the skin of the pod.

A nitric oxide (NO) ejector is positioned in the nose of the tank to release the NO. The NO reacts with ClO molecules in the stratosphere to produce Cl. Cl scattering of the UV light from the resonance light source is then detected by the photomultiplier.

A data system is programmed to modulate both the illumination source intensity and NO gas flow and to record the photomultiplier readings on magnetic tape.

Principal Investigator: Dr. Robert Young
Zonics, Inc.
Van Nuys, California

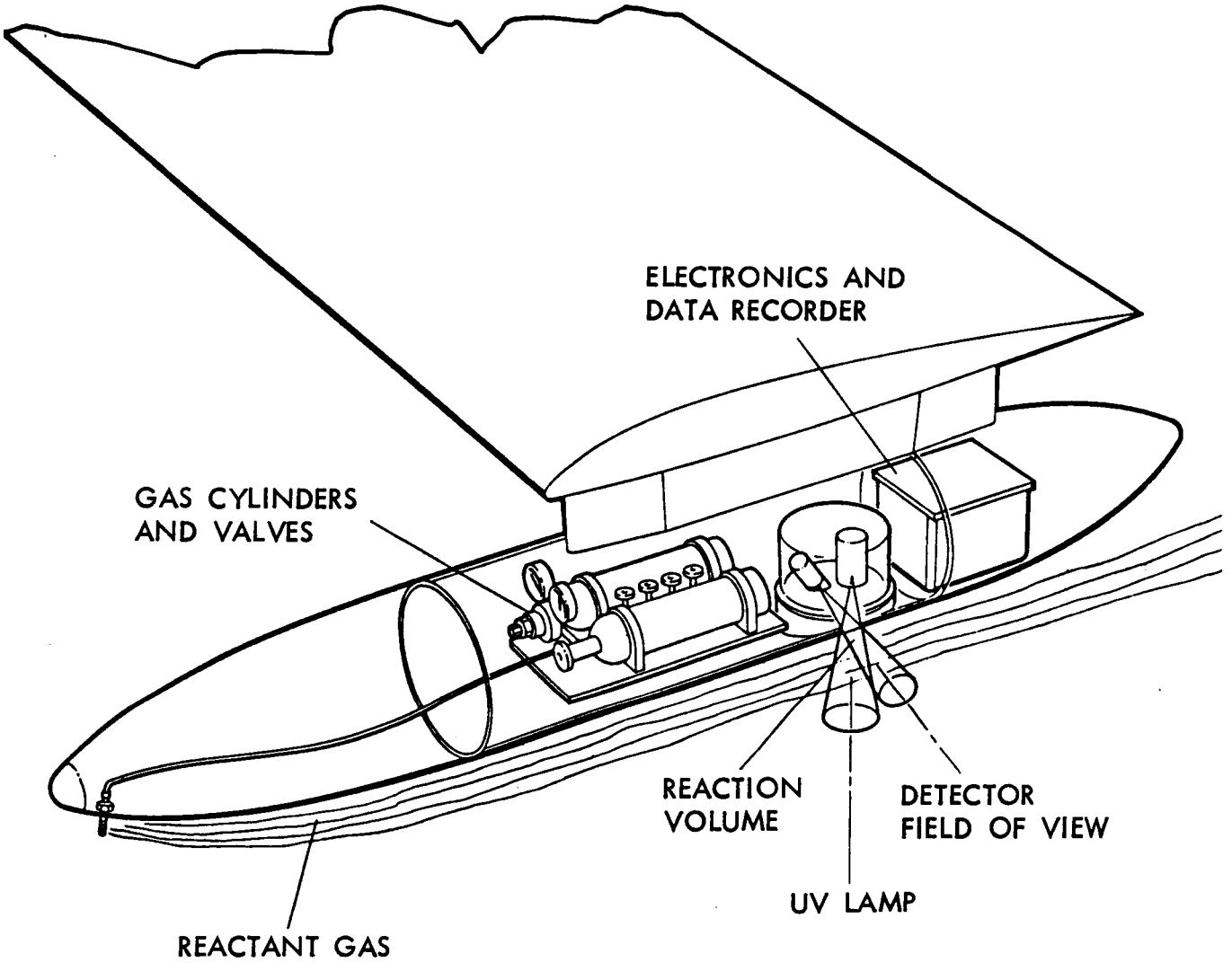


FIGURE B6 RESONANCE FLUORESCENCE EXPERIMENT

STRATOSPHERIC CRYOGENIC SAMPLER (SCS)

The SCS instrument is designed to measure halocarbons which are present in the stratosphere. The sensor is also capable of sampling methane and a wide range of hydrocarbons.

The apparatus is rack mounted in the lower equipment bay using the F88-500 hatch. It is a large system, weighing about 500 lbs and consists of four liquid nitrogen-cooled samplers and two individual whole-air samplers.

Each whole-air bottle will sample a volume of about 0.075 liters STP, while each cryogenic sampler will sample about 1000 liters STP. During flight, air enters the sampler through the air scoop by 3/4 inch flexible lines.

At 15.3 Km the air flow rate is greater than 70 STP liters/minute and decreases to about 50 STP liters per minute at 21.3 Km. This air is passed through the cryogenic samplers where the halocarbons are condensed with an efficiency of greater than 99 percent. The whole-air samplers are activated remotely by the pilot at the direction of the investigator.

These samples are then returned to the laboratory where they are analyzed by a combination of gas chromatography and mass spectrometry so that 0.1 PPT (1 part in 10^{13} by volume) can be measured.

Principal Investigators: Mr. Edward Inn
Dr. James Vedder
NASA/Ames Research Center
Moffett Field, California

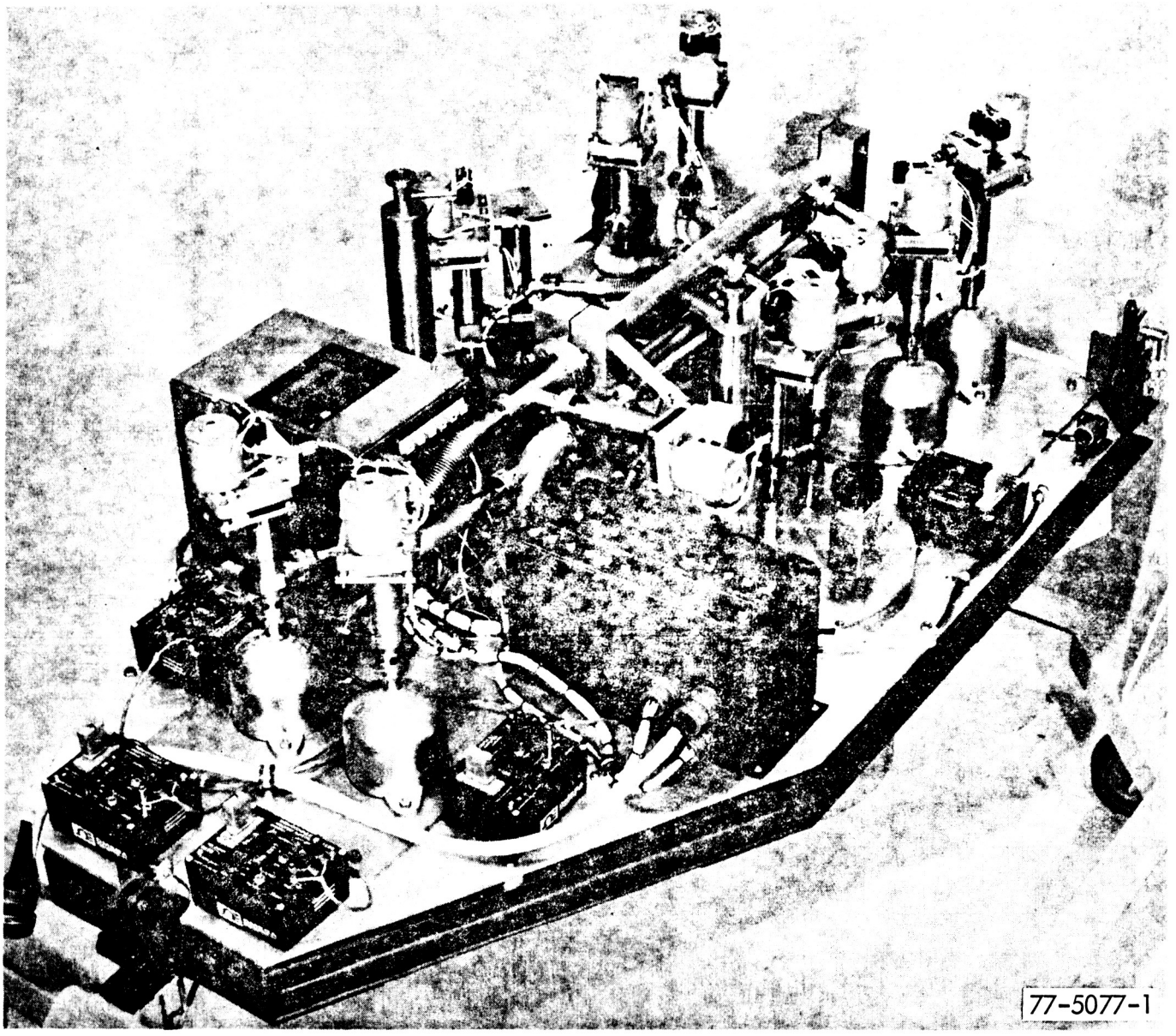


FIGURE B7 STRATOSPHERIC CRYOGENIC SAMPLER

STRATOSPHERIC AIR SAMPLER II
(SAS II)

The SAS II is an air sampling sensor designed to measure and record data on four atmospheric constituents during flights. Currently, the system is configured to measure O_3, NO, NO_2, and HNO_3.

The objective of the research is to provide data for stratospheric models by measuring NO, NO_2, HNO_3, and O_3 as a function of time and geographical location. A bench mark is then established against which future measurements can be compared. Additionally, the SAS II may observe the effects of man-made contaminants in the stratosphere and can be used to evaluate the effect of natural weather phenomena and volcanic activity of the stratospheric structure.

The instrument is mounted on a rack in the lower equipment bay and uses the F88-500 hatch. This hatch has been modified with a Rosemount total air temperature probe and an air scoop which is described under "Special Equipment." The SAS II weighs about 500 lbs. and can be flown simultaneously with sensors mounted in the wing pods.

Data is normally taken at 18.3 Km and 21.3 Km. At 21.3 Km cruise altitude, where the true airspeed of the U-2 is 206m/sec., the pressure developed at the inlet scoop is about 12 TORR above ambient. A flexible line carries the air flow to the instruments where continuous measurements of the four chemical constituents are made. The sampled data are recorded once per second on 9-track computer compatible magnetic tape, and in subsequent ground processing are averaged over three minute time intervals. The three minute

observation time is followed by a six minute automatic calibration cycle. System operation is fully automatic once system power is applied by the pilot. A manual measure mode is available and may be selected by the pilot for study of transient phenomena such as jet wake chemical studies.

NO is measured within a chemilunimescent reactor based on the reaction of nitric oxide with ozone to produce light which is then detected by a photomultiplier. O_3 is measured in the same manner by reversing the roles of the detected and reactant gases. NO_2 and HNO_3 are measured by being converted to NO in heated chemical converters, and then analyzed in the same fashion as NO.

Principal Investigator: Dr. Max Loewenstein
NASA/Ames Research Center
Moffett Field, Ca.

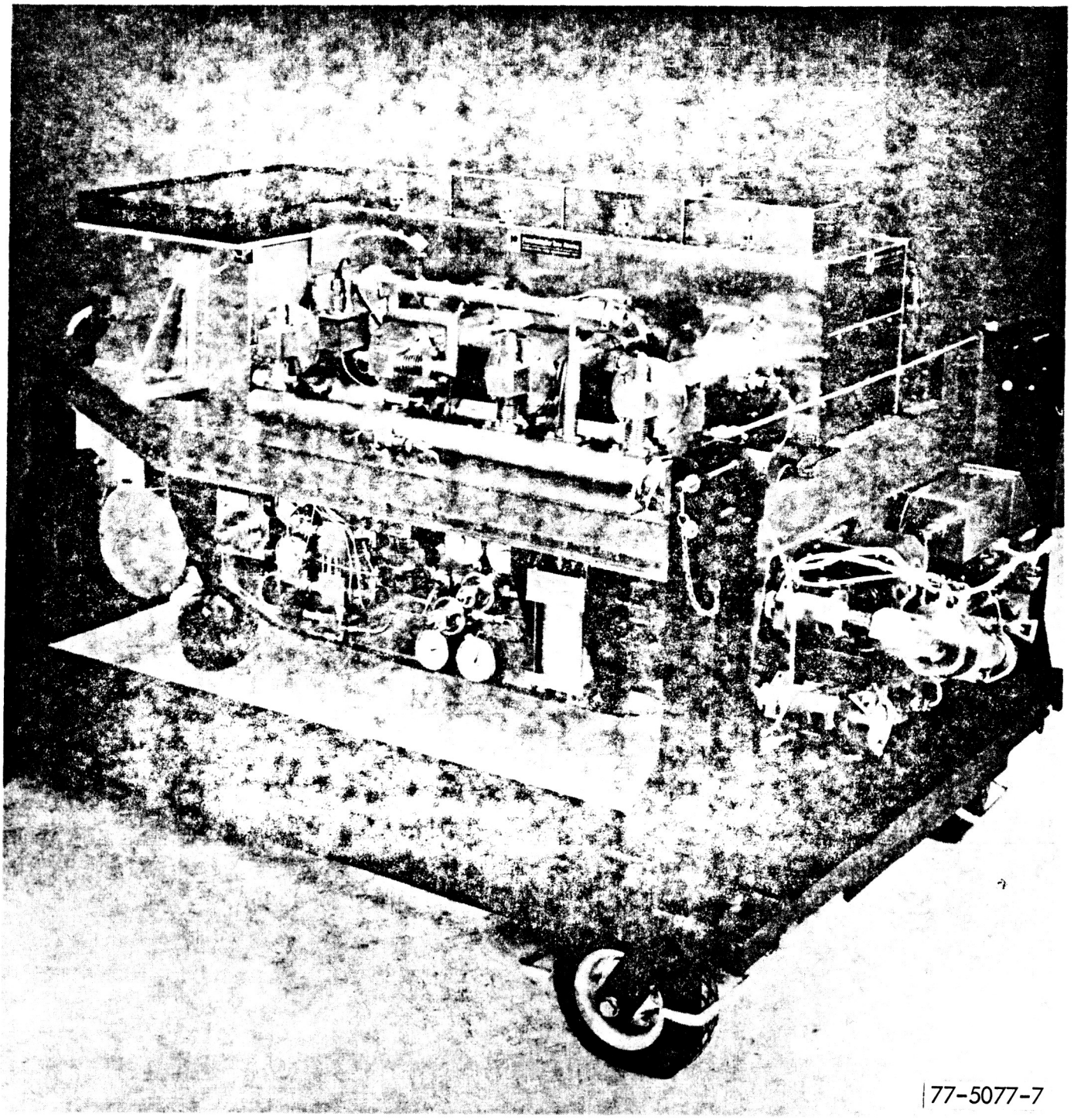


FIGURE B8 STRATOSPHERIC AIR SAMPLER II

HIGH SPEED INTERFEROMETER (HSI)

The HSI has been developed by the Jet Propulsion Laboratory in Pasadena with two primary program objectives. The first is to determine the abundance and abundance limits for the neutral molecular trace species with emphasis on molecules related to the stability of the stratospheric ozone layer. The second is to provide high resolution standard infra-red spectra of the stratosphere to aid in the design and evaluation of instrumentation for monitoring specific atmospheric pollutants.

The HSI is a high speed, stepped Michelson interferometer with an unapodized spectral resolution of 0.13 cm^{-1}. The instrument records 65,500 measurements in approximately 3 minutes and 40 seconds. Data is recorded as an interferogram onboard which, through ground processing, is transformed to absorption spectra covering the 2.0 to 5.5 micron region. From the spectra, mixing ratio profiles for trace gasses in the mixing range of 10^{-6} to 10^{-11} by volume are determined. The spectral region covered will yield data for H_2O, HCl, H_2CO, CO_2, CH_4, NO_2, and N_2O. Additionally, it is intended to identify chlorofluoromethanes and the lower hydrocarbons.

The HSI is mounted on a rack in the lower equipment bay and uses the F553-505 hatch with an IRTRAN II window installed in the aft, upper left portion of the hatch. The system is currently configured with an indium antimonide detector and has a field of view (FOV) of 1.25 degrees.

A sun tracking device allows the system to be pointed at and track the sun during sunset and sunrise. The HSI can also be reconfigured for flight on a balloon platform.

Principal Investigators: C. B. Farmer
O. F. Raper
NASA/JPL
Pasadena, Ca.

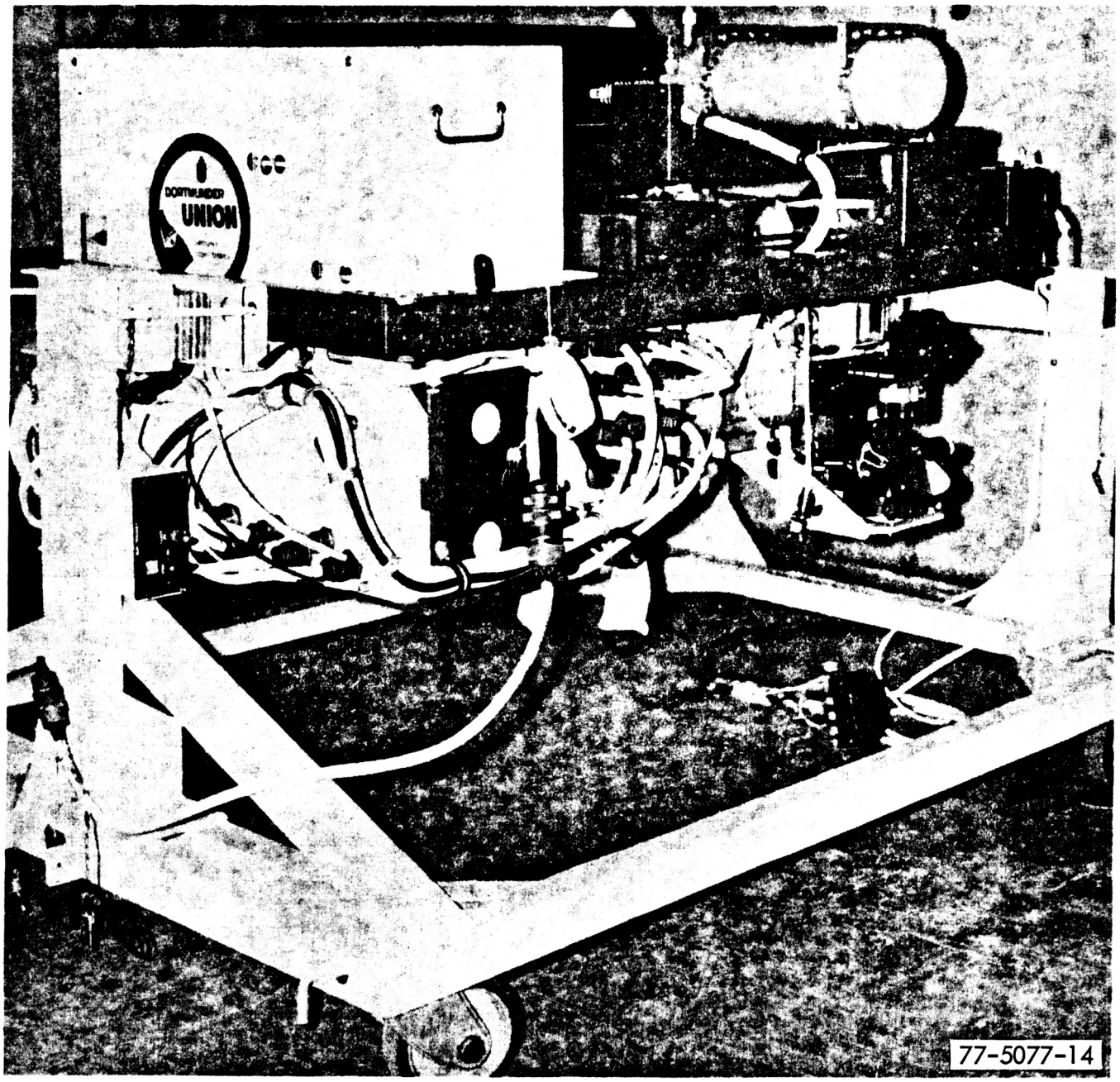


FIGURE B9 HIGH SPEED INTERFEROMETER

FILTER WHEEL INFRA-RED RADIOMETER (IRR)

The IRR has been developed by Lockheed Palo Alto Research Laboratories to measure atmospheric non-uniformities in the medium wave infra-red spectral region. The system consists of a downward-looking radiometer with a six-filter wheel which rotates in front of the radiometer. Several different filter wheels can be used, depending upon the spectral bands of interest. A four inch aperture and a liquid nitrogen cooled indium antimonide detector are also utilized.

The radiometer data is recorded along with various housekeeping data for computer analysis and transformation.

The filters give radiance responses which have their chief contributions from various levels in the atmosphere. Convective instabilities in the atmosphere together with wind shear are the physical mechanisms causing the measured fluctuations, in space and time. A minimum sensitivity of 0.1μ w/cm^2-sr-μm will be available so that, in conjunction with further data analysis, the microstructure of the temperature field can be determined.

The objective is to sound the atmosphere using infra-red emission in the medium wave region. Most of the pertinent atmospheric disturbances, e.g., waves, turbulence, clouds, occur below 20 km. The experimental results will represent the true state of the atmosphere rather than some smoothed, averaged description. The data will be useful for predicting mixing coefficients as a function of specific meterology, atmospheric isotropy, and, by means of spatial correlation analysis, the role of small scale eddy transport. Potential disturbed "layers" in the atmosphere are sought.

This system is hatch mounted on a F151-501 hatch and weighs approximately 240 pounds. An HP-307 tracking camera is also used.

Principal Investigator: Dr. Norman G. Kulgein
Lockheed Missiles & Space Company, Inc.
Palo Alto Research Laboratory
Palo Alto, Ca.

AEROSOL PARTICULATE SAMPLER (APS)

The APS is a small system, permanently mounted under the right wing of the U-2 aircraft for the collection of particulates in the 1 to 10 micron size range. The APS was developed to determine the concentration, composition, and physical nature of aerosols in the stratosphere so that the sources of the aerosols could be identified. The results then: 1) establish a global "bench mark" of stratospheric aerosols against which future measurements can be compared; 2) determine the effect of man-made sources of contaminants on stratospheric aerosol composition and on stratospheric turbicity; and 3) evaluate the effect of natural weather phenomena and volcanic activity on the stratospheric structure.

The system consists of a wing pylon about two feet long with three sealed capsules mounted along the side, each containing a wire collection surface. The collector extends a sampling surface which has been coated with silicone oil and is attached within a ring. The entire ring is exposed into the free airstream to collect particles. Particulate samples are protected from contaimination before, during and after collection.

Various types of thin wire meshes, plates or strands are thus exposed to the 200 m/sec airstream. As an example, the plate collection surface is about 18 to 20 cm^2 in area. Particles larger than about 3 microns are collected by inertial disposition while those less than one micron follow flow lines around the impaction surface and are not collected. Particle bounce-off is prevented by the oil coating on the collection surface.

The exposed capsules are returned to the laboratory after each flight where the particles are analyzed by individually removing them from the collection surfaces, mounting them on special surfaces for scanning electron microscope analysis and then washing them with xylene to remove the silicone oil.

Principal Investigator: Mr. Guy Ferry
Mr. Neil Farlow
NASA/Ames Research Center
Moffett Field, California

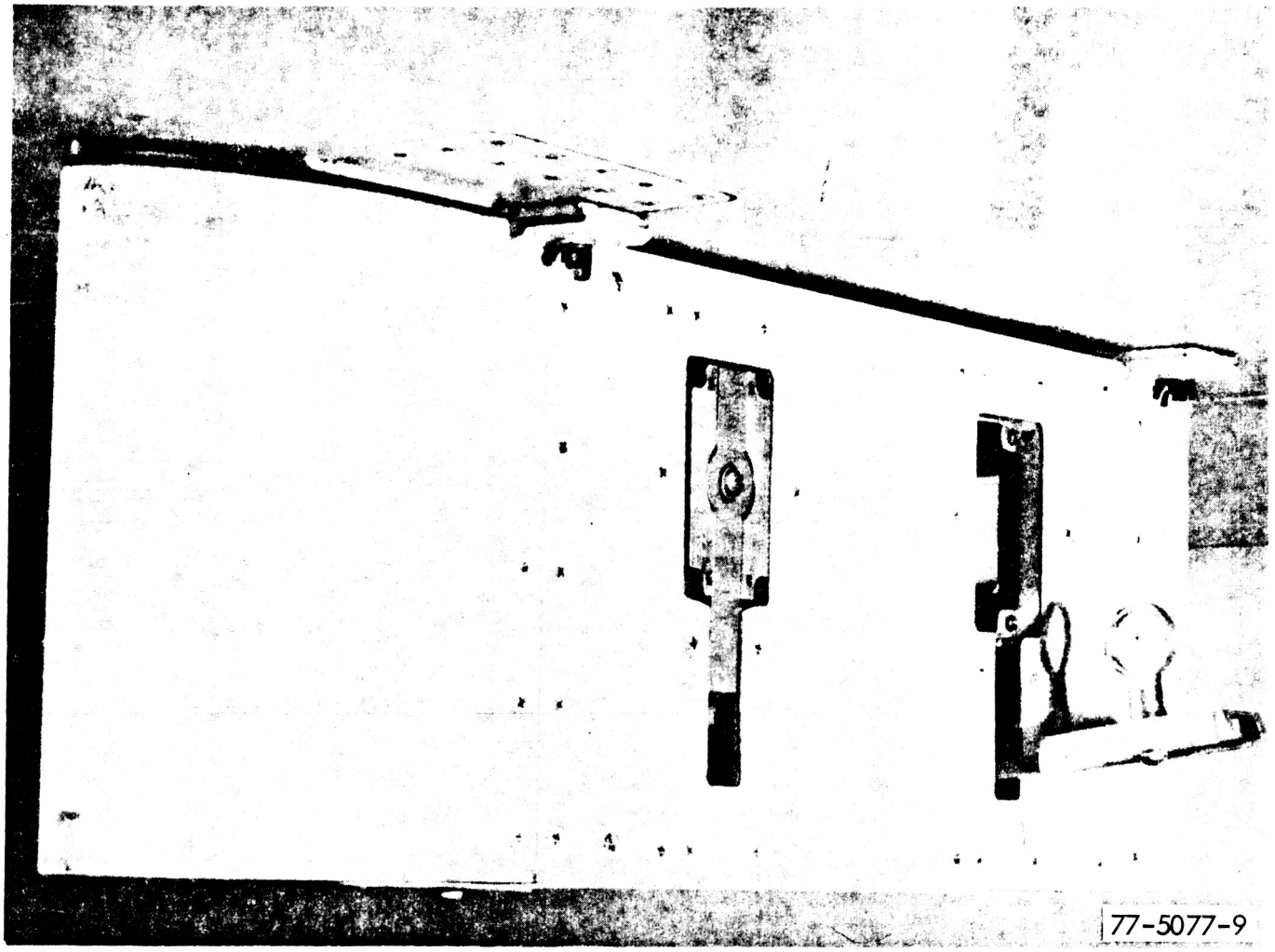


FIGURE B10 AEROSOL PARTICULATE SAMPLER

F-2 AIR PARTICULATE SAMPLER

This sampling system is maintained by AIRP and is available for use by interested experimentors.

The collecting system is contained in a pressurized drum mounted on a special Q-Bay lower hatch, complete with its own air scoop and remotely controlled air scoop entry door.

Six (6) grids, approximately 16 inches in diameter are available to be sequentially selected for particle exposure by the pilot, as instructed by the experimentor.

For analysis and calibration with existing historical data, investigators should be aware that the airflow rates are identical to similar systems such as the U-1 which have collected data for Project Airstream. The system has been flown to collect data simultaneously with balloons.

The experimentor is responsible for the supply of filter paper, assembly of the filters into the grids and analysis of the collected particles.

Inquiries and questions regarding the anticipated use of this device may be directed to the U-2 Missions Manager at NASA Ames.

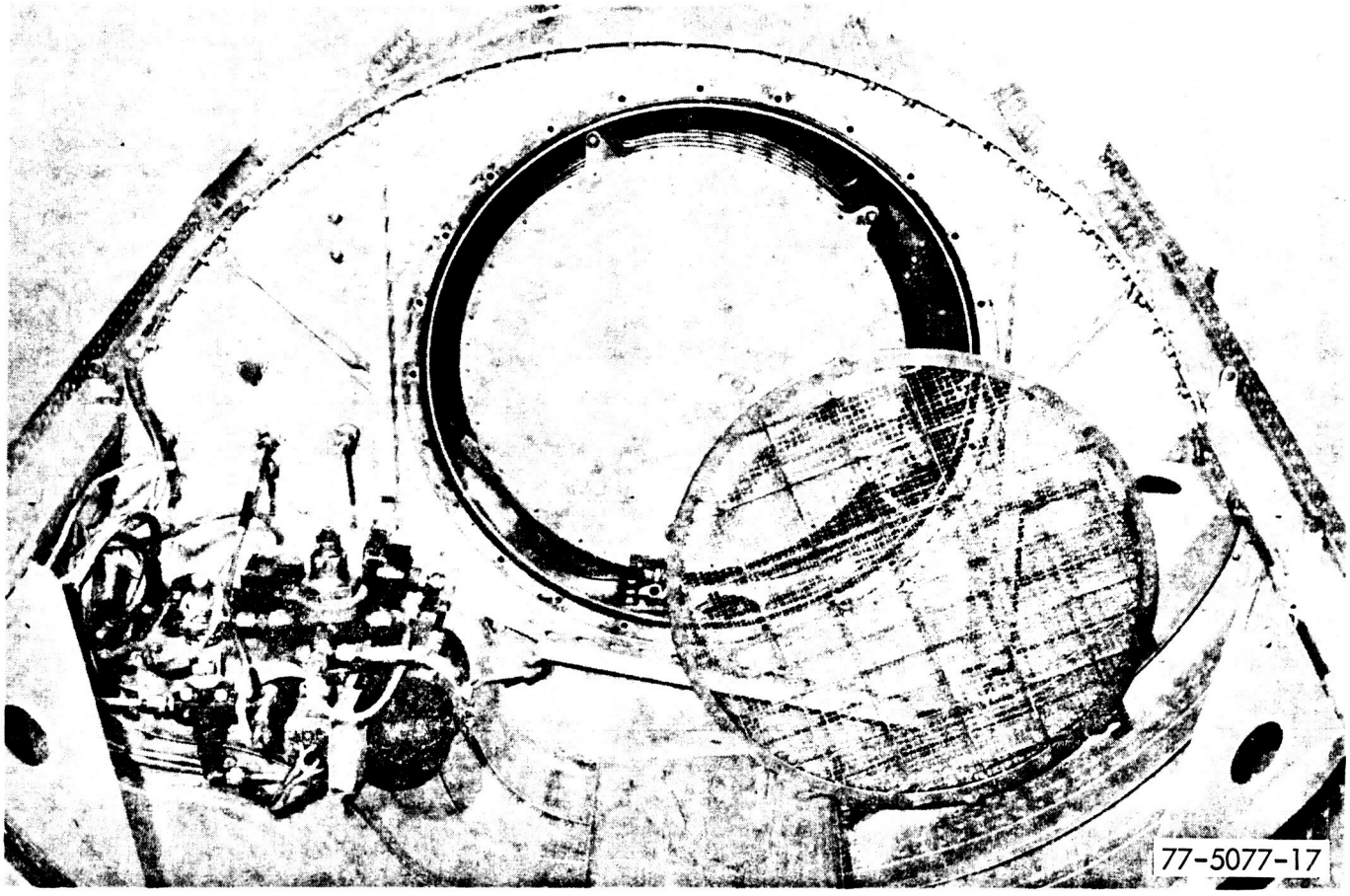


FIGURE B11 F-2 AIR PARTICULATE SAMPLER

EARTH OBSERVATIONAL SENSORS

INTRODUCTION

There are several electronic sensors currently in an operational status at this time. Each of the systems is a scanning type device which is potentially available to a variety of users. Inquiries and coordination for use of any of these scanners should initially be directed to the individual indicated in the sensor description.

OCEAN COLOR SCANNER SYSTEM

The Ocean Color Scanner (OCS) has been developed and is operated by NASA Goddard as a prototype system for the Coastal Zone Color Scanner (CZCS) to fly on Nimbus G. Its main purpose is to apply and evaluate the data processing techniques planned for the CZCS and to determine the impact of atmospheric scattering on ocean color imagery.

The OCS is a ten-channel multispectral scanner with a 90° total scan angle and spatial resolution of 3.5 milliradians. The peak wavelengths for the 10 channels are:

Band 1	-	427nm	Band 6	-	622nm
Band 2	-	465nm	Band 7	-	662nm
Band 3	-	500nm	Band 8	-	701nm
Band 4	-	544nm	Band 9	-	735nm
Band 5	-	582nm	Band 10	-	774nm

When flown at an altitude of 65,000 ft, the scan rate and optical system are adjusted so that the pixel size approximates 227 feet and the scan lines are contiguous. A Cassegrain telescope and its associated lens system focuses the scanned surface information on a grating and the emergent light waves are picked up at proper positions by glass filament light pipes. The desired spectral information is then conducted to silicon type diode detectors (PIN types).

In the detectors, the collected light energy is converted to electrical signals that are amplified, processed, and recorded. Synchronizing pulses, housekeeping information and calibration signals are multiplexed with the detector signals to form a composite output voltage that may be readily processed.

The output of the scanner is recorded on one inch, 14 track magnetic tape in analog form. Additionally, all of the 10 channels are also recorded in PCM digital format. All PCM processing and data reduction from this sensor is accomplished at GSFC, Greenbelt, Maryland. The resulting Computer Compatible Tape (CCT) can be processed at Ames Research Center utilizing the IDIMS system in the AIRP Data Facility. (See Section EIV for a description of the IDIMS data handling system).

Use of OCS data includes the remote sensing of ocean color to identify and map regions of high food productivity, upwelling regions, extent of red tide, sediment concentration off the coast, coastal zone inventory, etc.

The OCS is rack mounted with four (4) Vinten Cameras and uses the F291-501 or -502 hatch. This is a downward looking system through a borosilicate optical window. Filters may be installed as required by specific mission requirements.

The system was designed and built by:

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

Dr. William Barnes

Since primary data reduction must be accomplished by NASA Goddard, for contacts for use of this instrument should be made through:

Dr. William L. Barnes

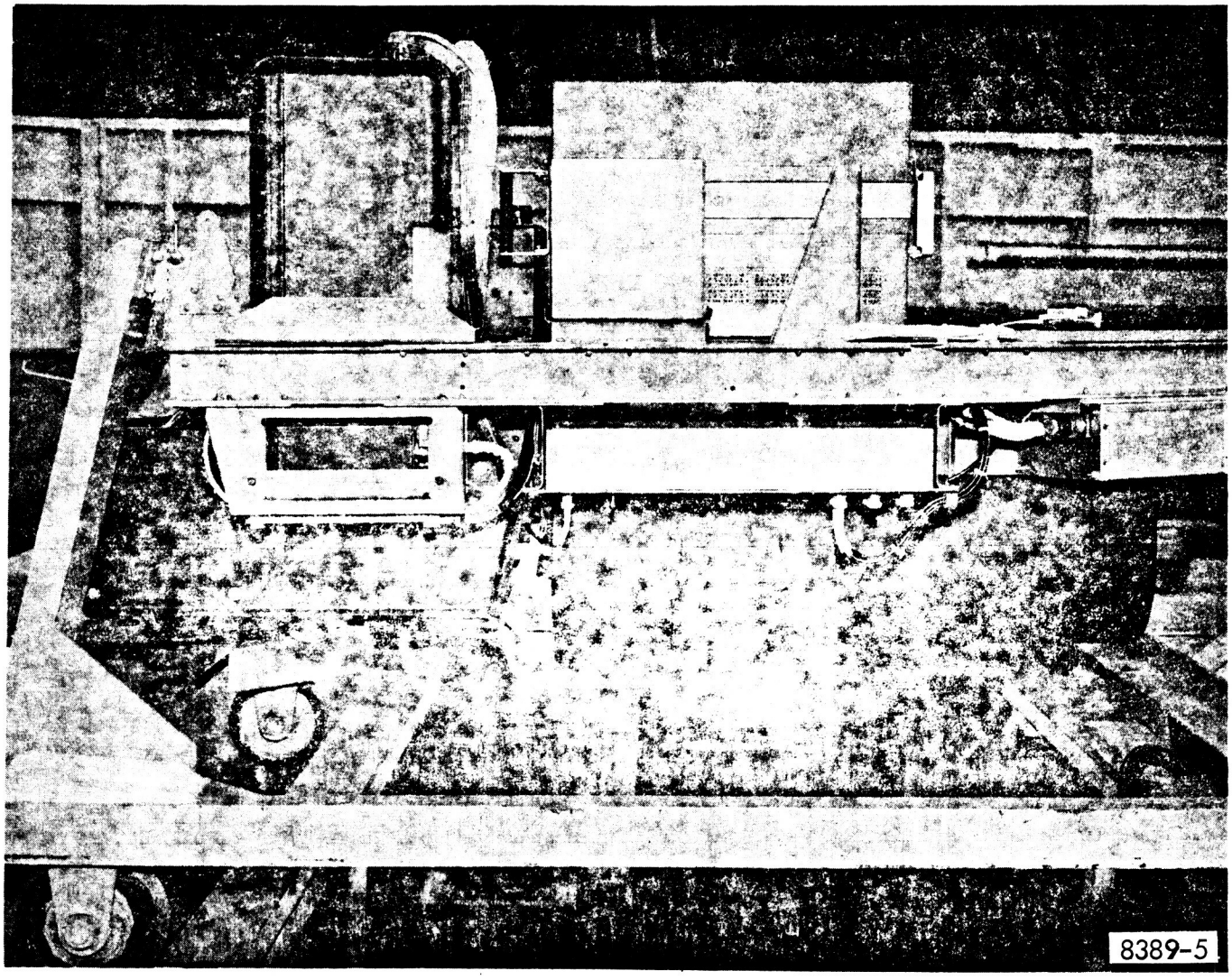


FIGURE C1 OCEAN COLOR SCANNER

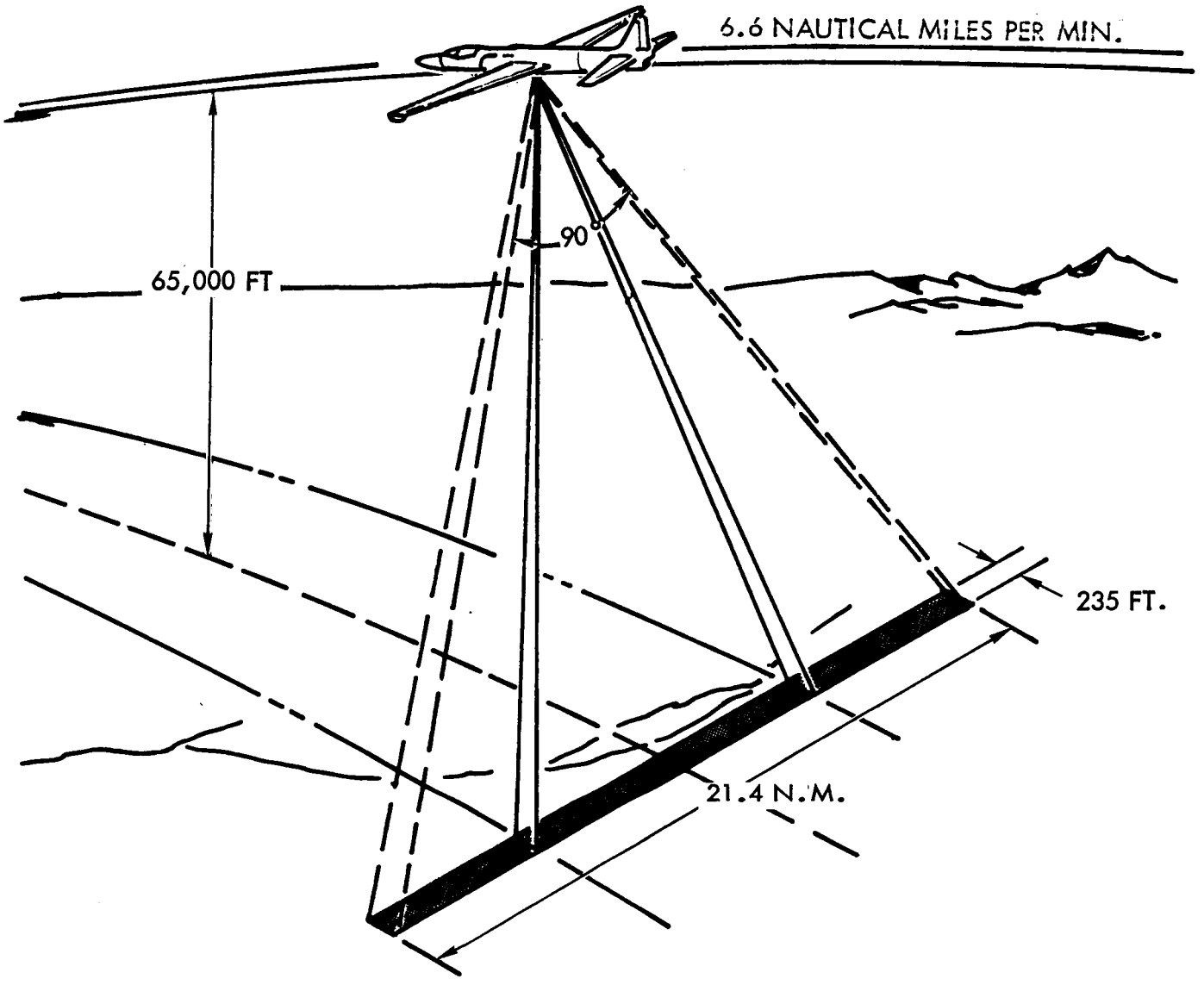


FIGURE C2 OCEAN COLOR SCANNER COVERAGE

HEAT CAPACITY MAPPING RADIOMETER

The Heat Capacity Mapping Radiometer (HCMR) is a NASA Goddard built thermal scanner to compare thermal phenomena with visible spectra phenomena. The same type of mirror scanning system is used here as is used in the Ocean Color Scanner. The optical system focuses the scanned surface information on both visible and infra-red portions of the spectrum (.5-.7 micrometers and 10.5-12.5 micrometers).

The HCMR has a 90^{o} scan angle and a 2.8 milliradian instantaneous field of view (IFOV). This spatial resolution provides a pixel size of approximately 182 ft. The scan rate is adjusted so that the scan lines are contiguous at the desired aircraft speed. The scanner utilizes a silicon detector in the visible channel and a mercury cadmium telluride (Hg Cd Te) detector for the infra-red. The IR detector is cooled by mounting the detector in a dewar that will hold for approximately six (6) hours. Liquid nitrogen is used as the coolant. Thermal resolution is $0.2^{o}C$. All data is recorded as an analog signal on 1/2-inch magnetic tape aboard the aircraft. Synchronizing pulses, housekeeping information and calibration signals are multiplexed with the desired spectral information to form a composite output signal that may be readily processed. Also, an on-board digitizer is used to digitize the visible and IR channels prior to recording on a single track of the recorder.

The HCMR scans large areas in a short period of time with virtually all of the atmospheric effects that will be seen from a satellite platform.

This simulation will allow investigators time to develop techniques for analysis of:

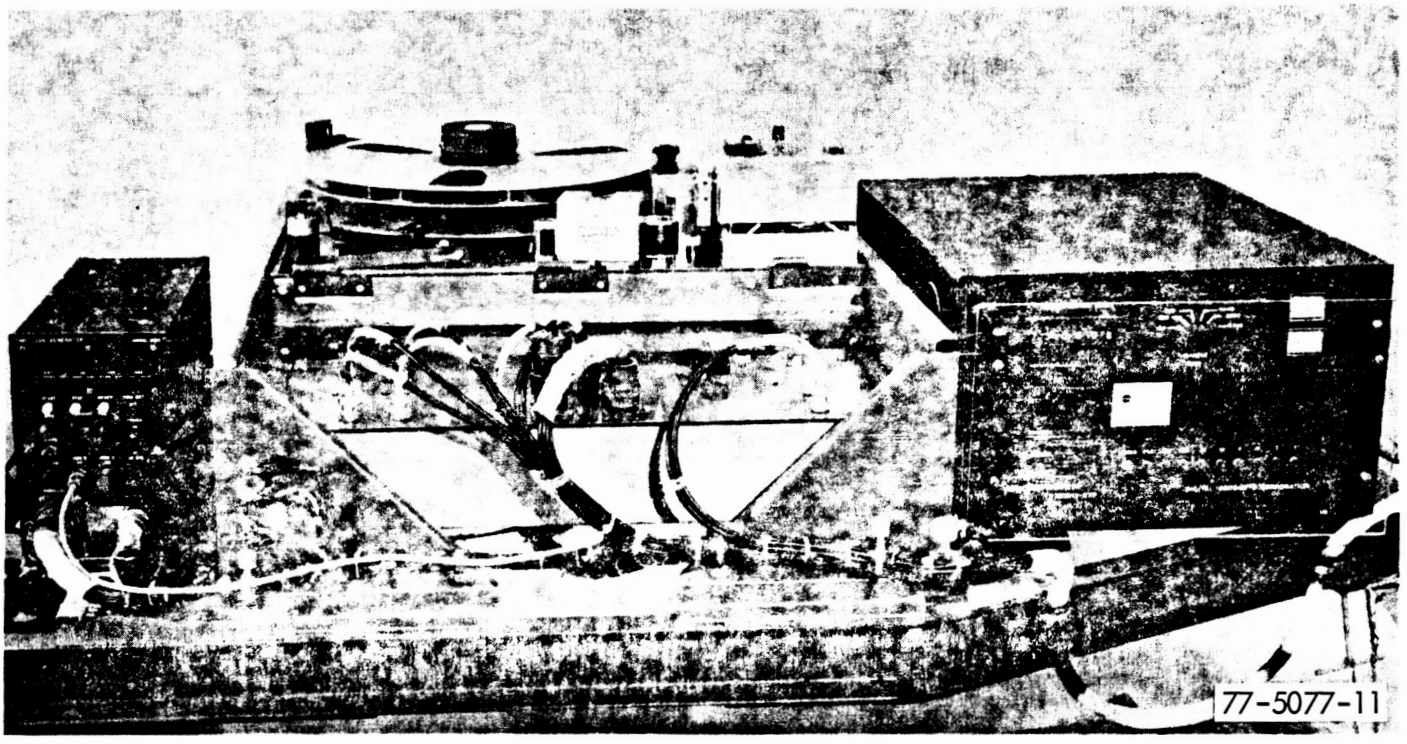
1. Diurnal variations for measurement of soil moisture.
2. Thermal inertia modeling.
3. Thermal modeling of lakes and their development as calibration sources for satellites with thermal sensors.
4. Water seepage in mining areas.
5. Thermal anomalies.
6. Wetland studies.
7. Thermal pollution studies in offshore and inland waters.
8. Rapid and accurate crop production inventories.

The HCMR is mounted on a 75F177-504 hatch. The thermal scanner head is sealed in an unpressurized cover assembly and directly views the ground without an intervening window.

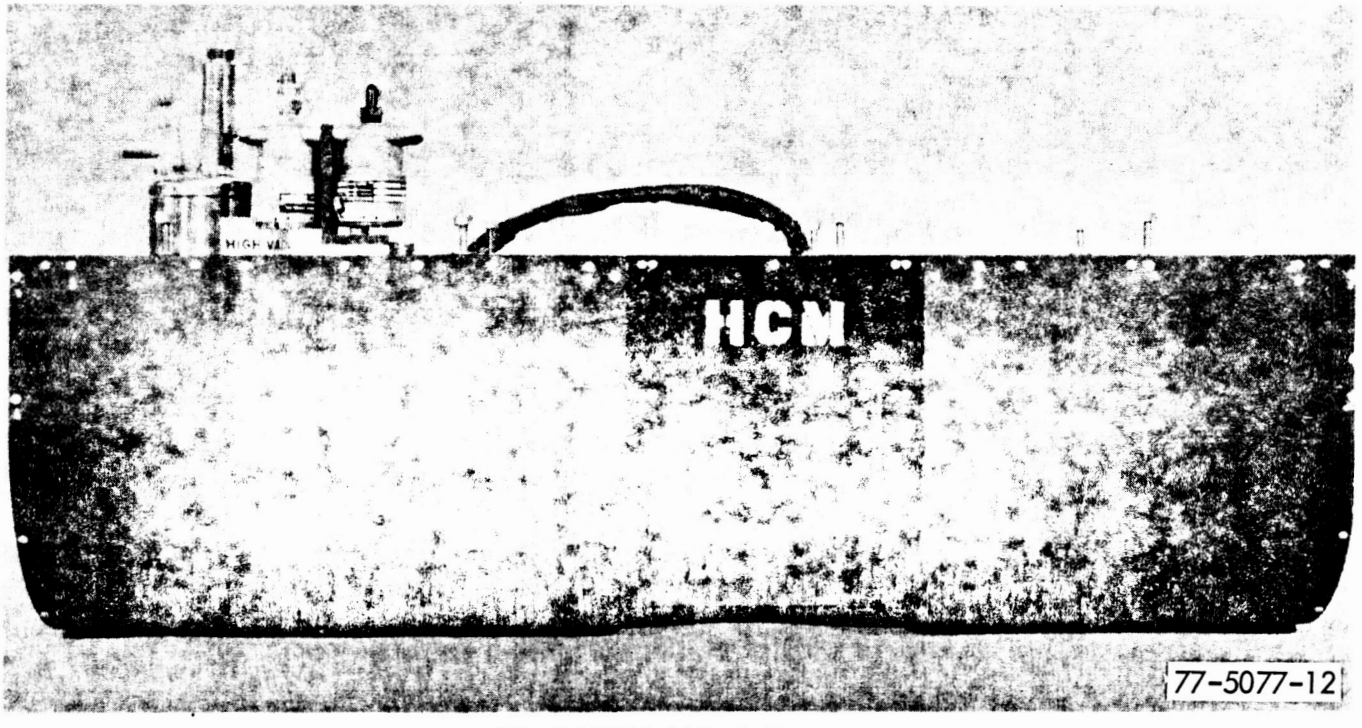
The HCMR was designed and built by:

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771
Dr. William L. Barnes

Since data reduction must be accomplished by NASA Goddard all contacts for use of this instrument should be made through Dr. William L. Barnes.



RACK MOUNTED EQUIPMENT



LOWER HATCH MOUNTED SENSOR

FIGURE C3 HEAT CAPACITY MAPPING RADIOMETER

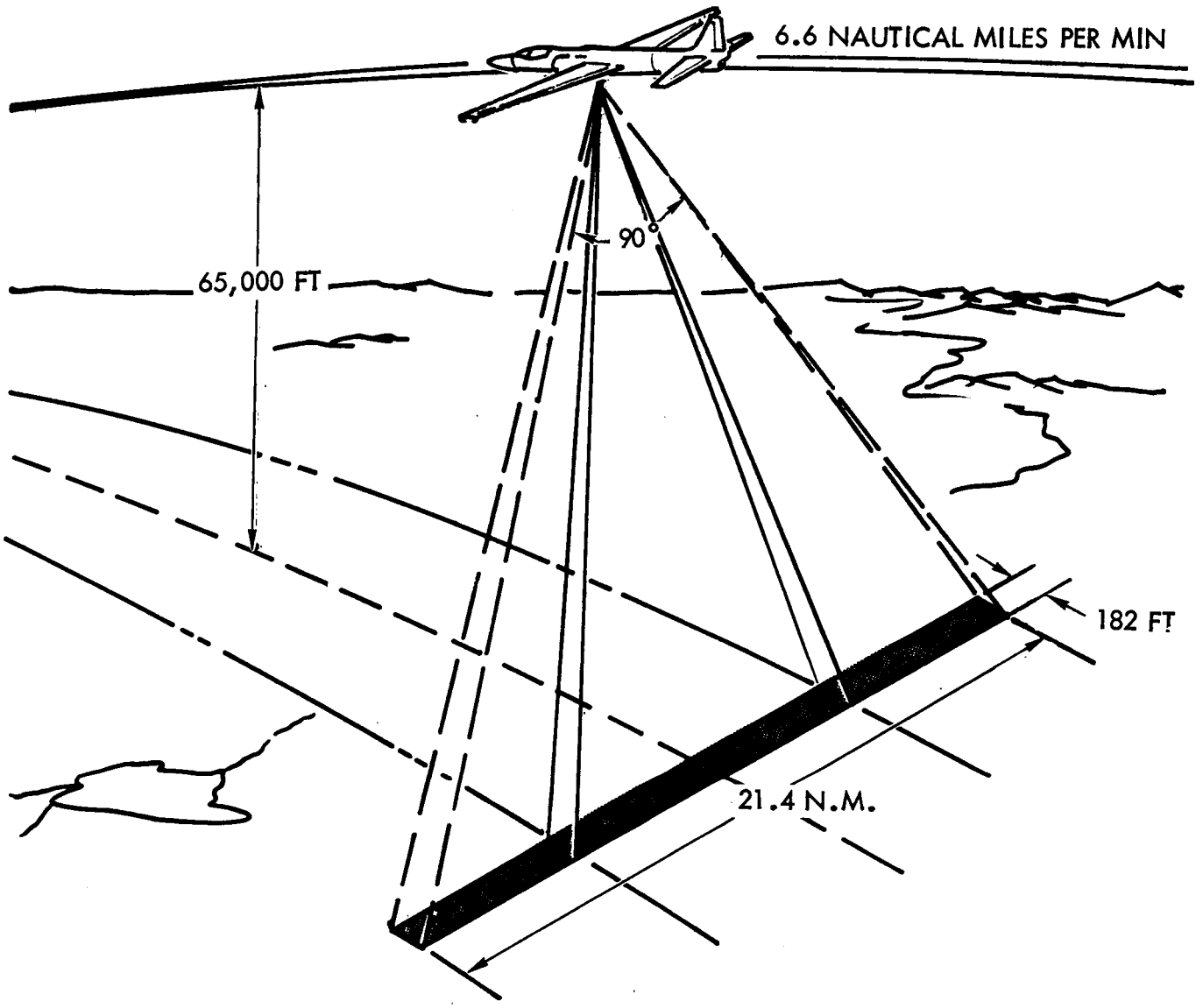


FIGURE C4 HEAT CAPACITY MAPPER RADIOMETER COVERAGE

THERMAL INFRA-RED SCANNER (TIRS)

The TIRS sensor is an IR line scanner which is owned and operated by AIRP at NASA Ames for use by interested investigators. The video system is roll stabilized and a Vinten camera, described in Section AI, is installed as a tracking camera.

The TIRS uses a specially modified equipment bay lower hatch which includes a segmented IRTRAN window. The system data output is PCM encoded onto a digital tape recorder and is recorded in bi-phase ENRZ. The data format is pixel interleaved as follows:

pixel 1, channel 1; pixel 1, channel 2;
pixel 2, channel 1; pixel 2, channel 2; etc.

Applications for this sensor are: soil moisture studies, snow pack investigations, fire reconnaissance and assessment, and geologic studies. It is particularly applicable to the study of thermal pollution.

Sensor specifications are:

Number of channels	- One (1) channel in the ~~3 to 5~~ 2 to 3 micron range and one (1) channel in the 8 to 14 micron range.
I FOV	- 1 milliradian
Scan rate	- 10 RPS

Sensor specifications are:
(Continued)

Scan angle	- 90°
Resolution	- From an altitude of 65,000 ft. approximately 65 ft.

This sensor is operated by the Airborne Instrumentation Research Project, Ames Research Center/240-6, Moffett Field, Ca. 94035.

Since data reduction must be accomplished by NASA Ames, inquiries regarding the use of this instrument should be directed to Mr. John Arvesen.

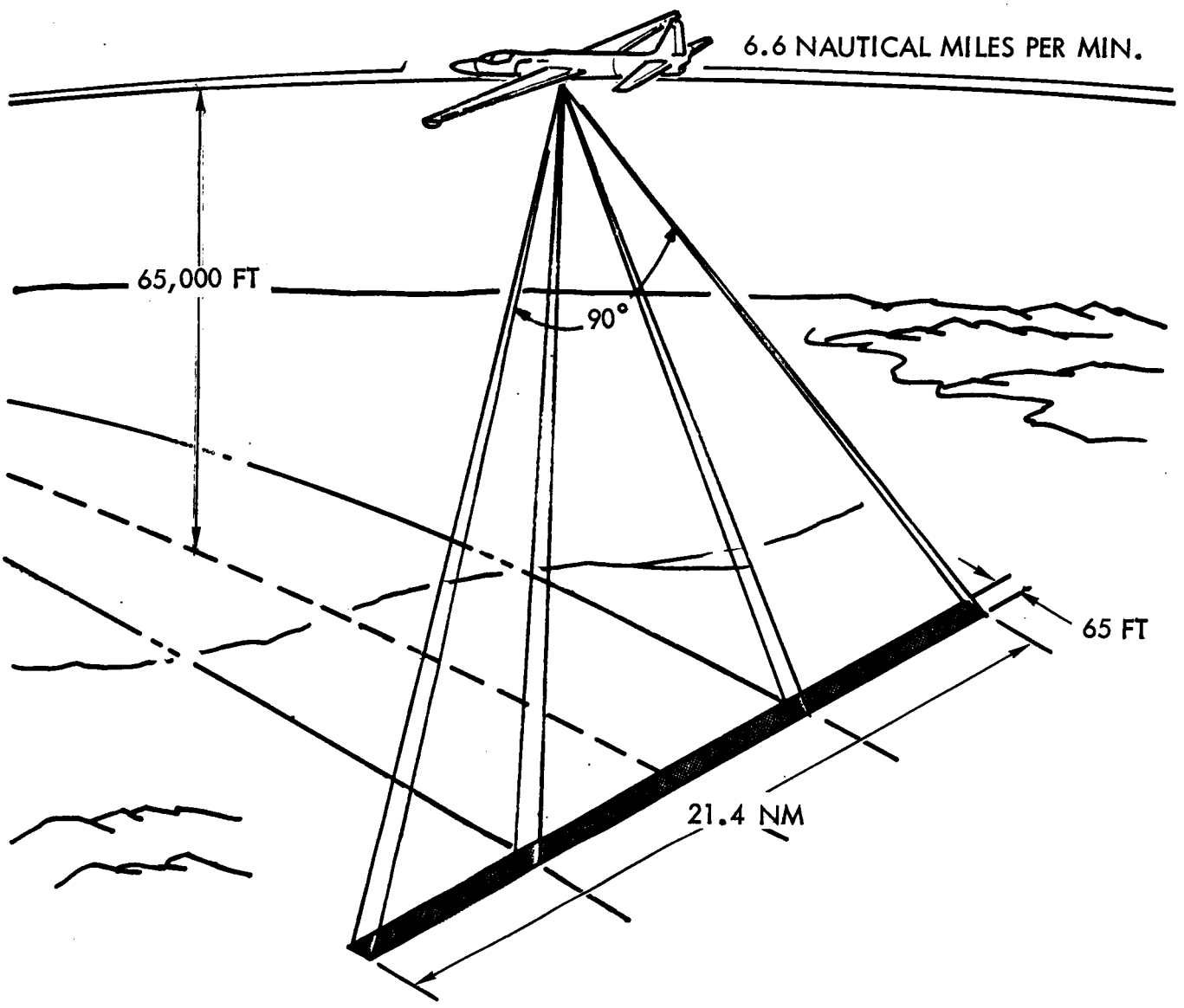


FIGURE C5 TIRS IR SCANNER COVERAGE

SPECIAL EQUIPMENT CONFIGURATIONS

INTRODUCTION

In this section of the handbook, special configurations of existing airscoops, sampling devices, and upward viewing hatch facilities are discussed. This particular section of information will be expanded by amendments to the handbook as new configurations are developed and become operational.

New experimentors should be aware that some of the capabilities described here are the property of present or previous experimentors and arrangements must be coordinated through the NASA Ames U-2 Missions Manager to assure availability of a given device.

EAQ-41 AIRSCOOP

The EAQ-41 Airscoop installation was developed specifically for the Stratospheric Projects Office at NASA Ames Research Center, Moffett Field, California. This scoop is currently installed on one (1) F88-500 Hatch Assembly and any anticipated use of this device may be coordinated through the U-2 Missions Manager at NASA Ames.

The assembly is a simple device consisting of two (2) one inch diameter stainless steel tubes, bent to be parallel to the line of flight and mounted on the lower centerline at the aft end of the hatch assembly.

The airflow developed by this device is dependent on the back pressure produced by the attached air sampling experiment. No flow augmentation is provided.

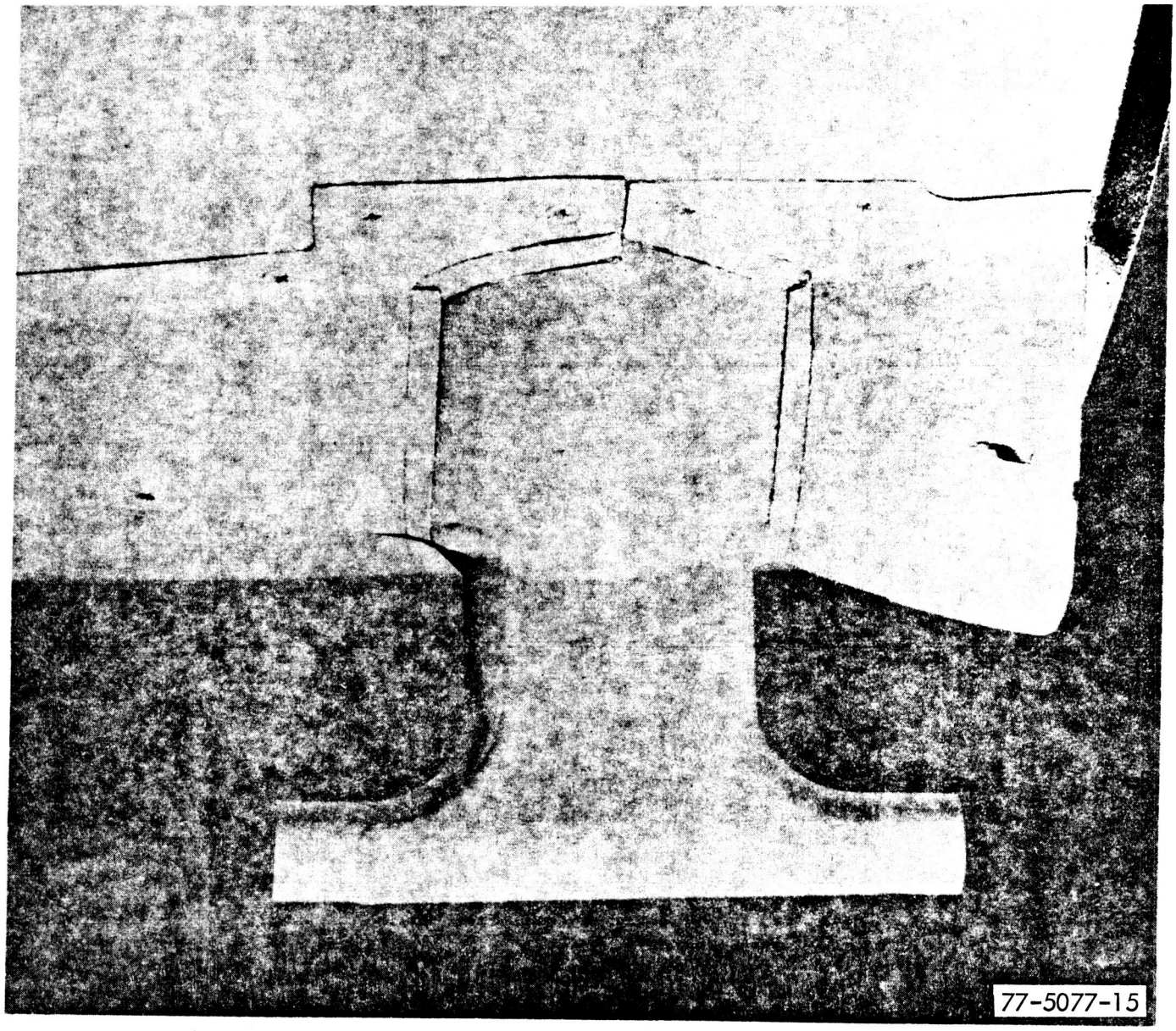


FIGURE D1 EAO-41 AIRSCOOP

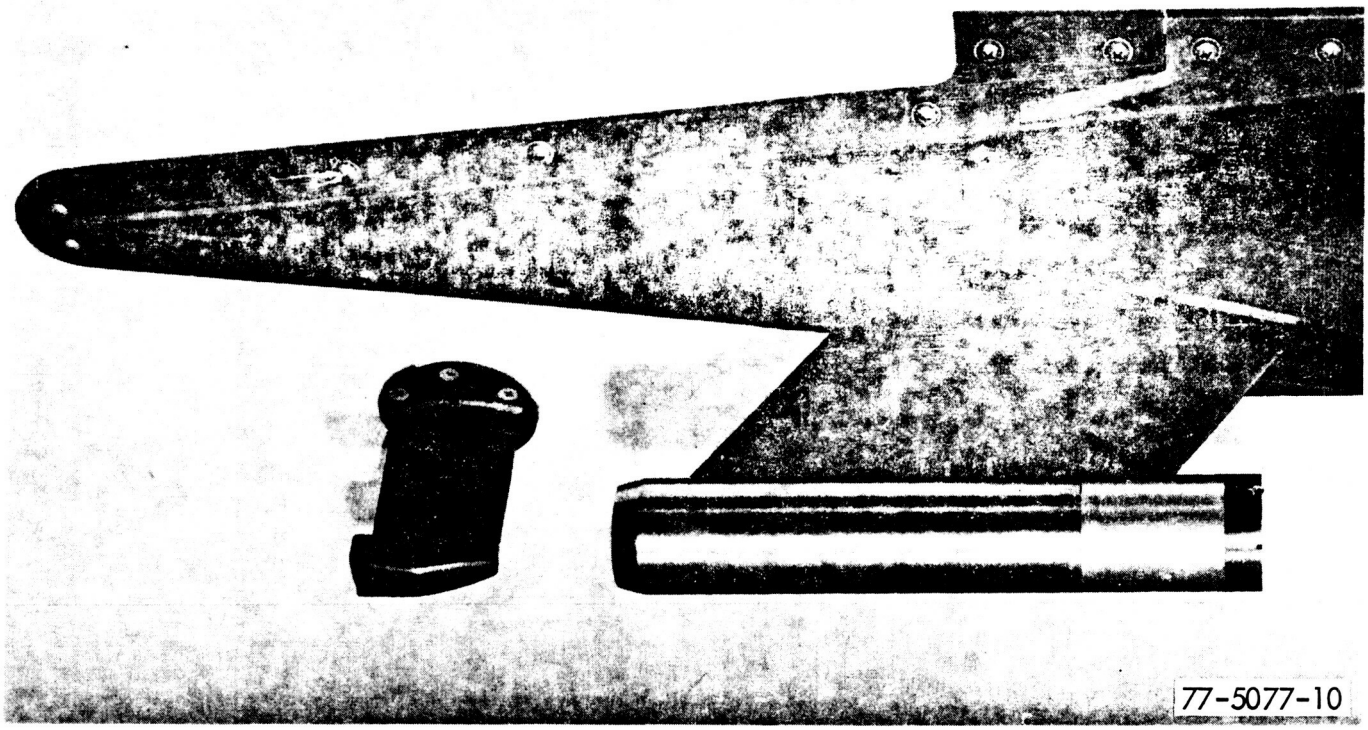
NASA AMES AIRSCOOP

This airscoop assembly was designed and developed by the Stratospheric Projects Office at NASA Ames Research Center, Moffett Field, California. This scoop is an alternate installation to the EAQ-41 scoop assembly described in Section DI of this handbook. It has been used with the Stratospheric Cryogenic Sampler (SCS) and the Stratospheric Air Sampler II (SAS II).

This device is the property of the NASA Ames Airborne Stratospheric Projects Office and any contemplated use must be coordinated through the U-2 Missions Manager at NASA Ames

The device is similar in operation to that of the EAQ-41 scoop described in Section DI except that the addition of the annular ring at the rear of the device augments air flow thereby permitting either higher air flow or a greater pressure drop through the attached air sampling experiment.

A Rosemont True Air temperature probe is installed on the hatch and is available for temperature data recording with suitable wiring and recording devices.



VIEW LOOKING UP

FIGURE D2 NASA AMES AIRSCOOP

UPWARD LOOKING HATCH CONFIGURATION

In the operation of the U-2 program at NASA Ames, there have been requirements for the development of upward looking apertures. Two (2) such installations are described in this section.

A. Upper Hatch Window

For use by upward looking instruments, a quartz window has been installed in the Q-Bay upper hatch of both U-2 airplanes stationed at NASA Ames as shown in Figure D3.

The window specifications are:

- Quartz window - optical quality, flat.
- 0.54 inch thick
- Clear Area - 6.125 inches diameter

The use of this hatch window must be coordinated with the U-2 Missions Manager at NASA Ames. Investigators should be aware that this hatch window is currently in use by an investigator.

B. Modified Upper Hatch Installation

One (1) Q-Bay upper hatch assembly has been modified to accept rotating experimental devices. The hatch has a 20-inch inside diameter bearing centered at F.S. 278 as shown in Figure D4.

Use of this hatch requires a pressure plate at the bearing plane or a pressure can mounted to the underside of the hatch to maintain proper pressure in the Q-Bay. This hatch also requires an external

metallized fiberglas fairing to maintain airplane contour over the hatch area while accommodating the installed experiment. The payload mounted on the hatch assembly cannot exceed a total installed weight of 389 pounds, including installation modifications.

This hatch is currently in use by an investigator and any proposed use should be discussed and coordinated with the U-2 Missions Manager at NASA Ames.

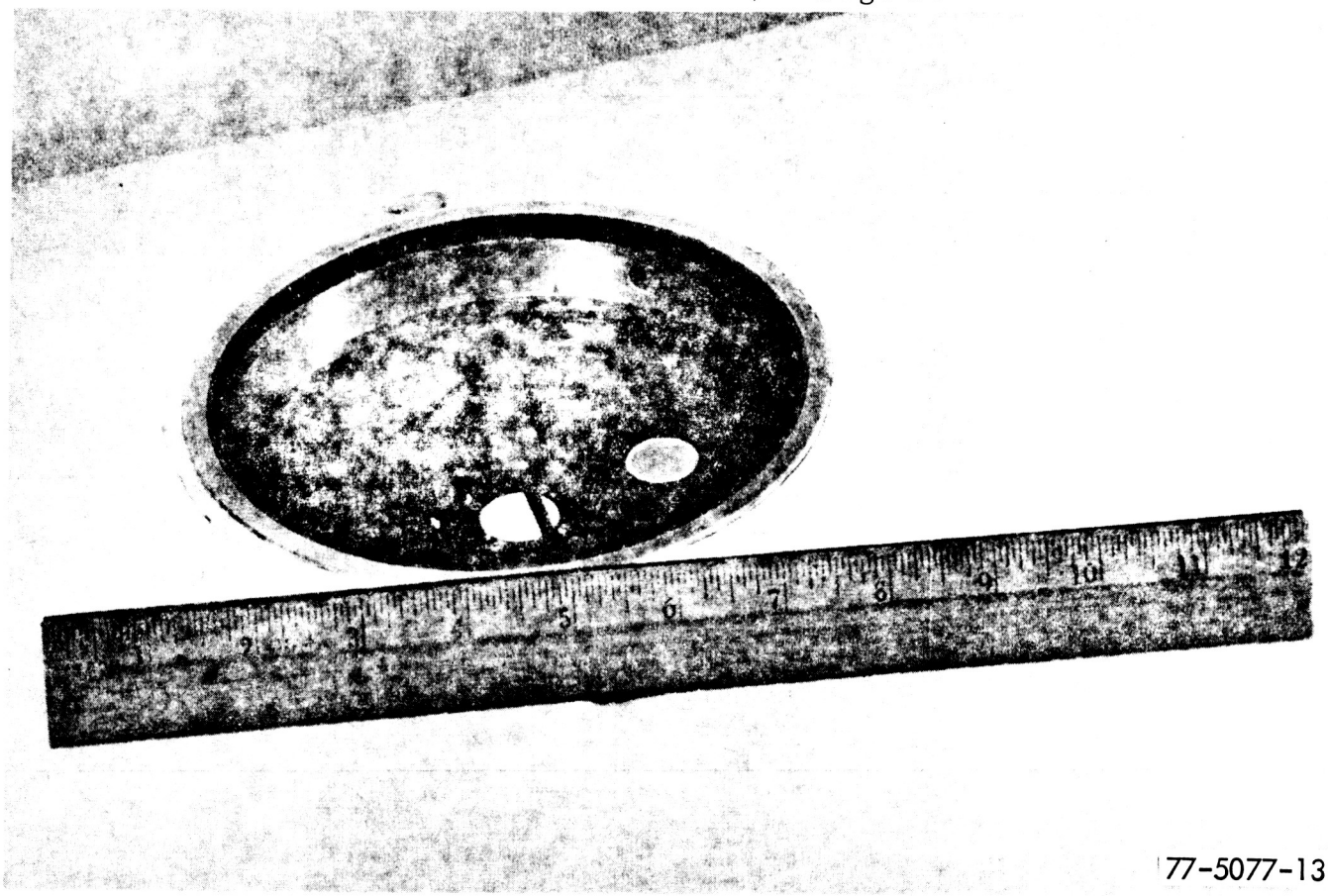
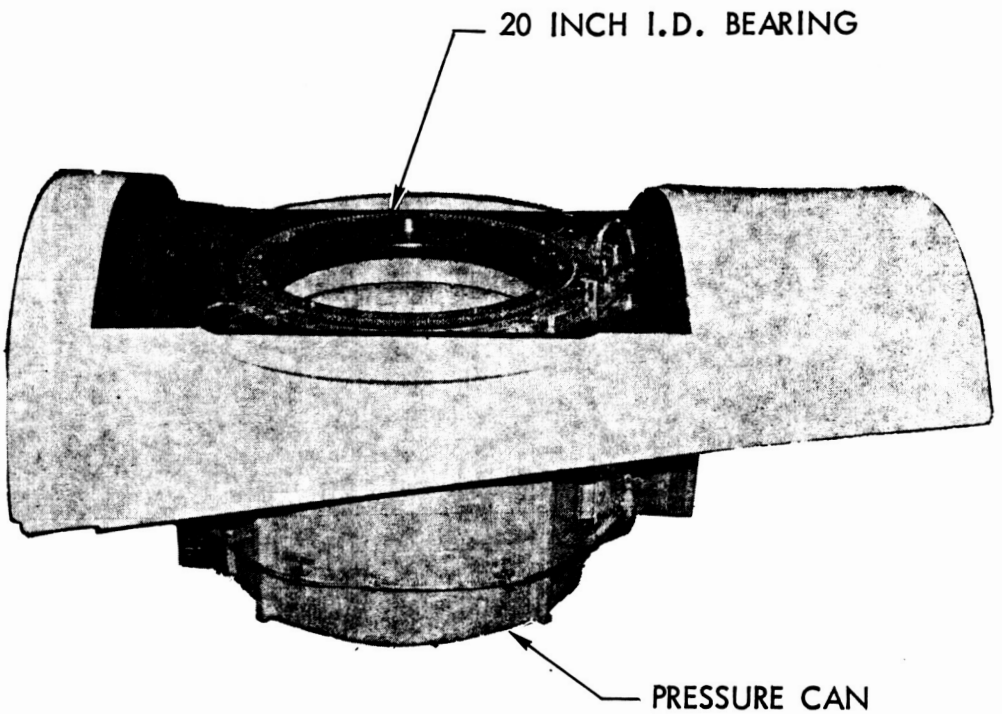


FIGURE D3 UPPER HATCH WINDOW



76-5399-2

NOTE:

THE PRESSURE CAN AND HATCH CONFIGURATION, AS SHOWN, IS IN USE BY AN EXISTING EXPERIMENTOR.

FIGURE D4 MODIFIED UPPER HATCH INSTALLATION

CANOE AIRSCOOP INSTALLATION

An airscoop is mounted in the canoe section of the aircraft. The canoe is a shallow area above the engine on top of the fuselage. The airscoop is in use currently, but similar installations can be accommodated, particularly if they are small. The unpressurized canoe area will hold up to 100 pounds of payload with dimensions approximately 8 ft long, 5 inches high, and 16 inches wide.

The present airscoop can accommodate a canister approximately six (6) inches in diameter and sixteen (16) inches long. This canister is equipped with inlet and outlet air valves to permit control of airflow through the canister by the pilot as instructed by the experimentor. See Section BIII for a detailed description of this experiment.

There are no data available as to the flow rates through the existing system.

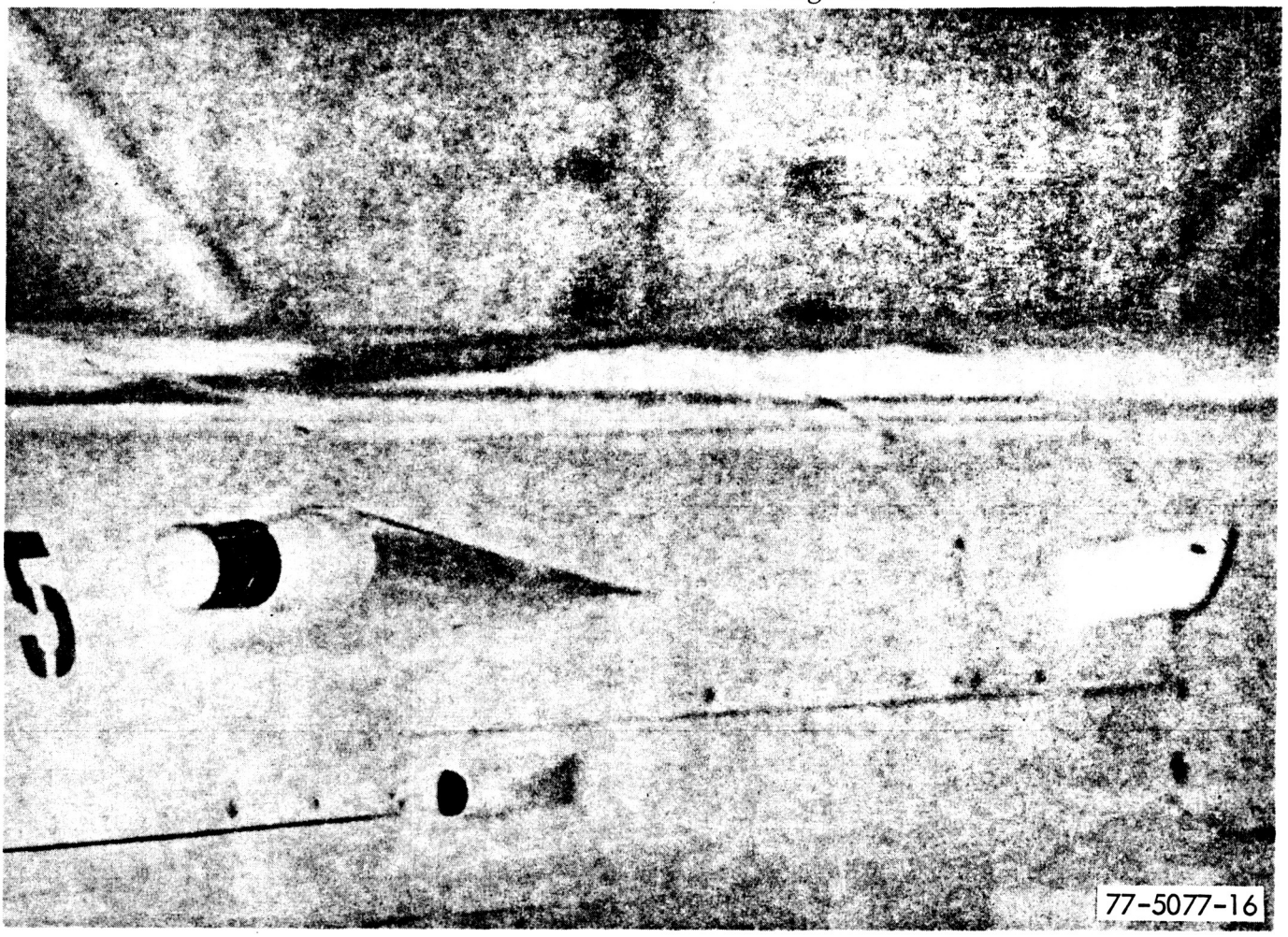


FIGURE D5 CANOE AIRSCOOP INSTALLATION

WING MOUNTED TANK CONFIGURATION

The wing mounted tanks can be used to carry instrumentation. The approximate dimensions are shown in Figure D6. More detailed information on the configuration is available in the Investigators' Handbook (Volume 1).

Investigators should be aware that these tanks are not pressurized, no temperature control is provided and in the event of an emergency they can be dropped at the pilot's discretion. The tanks are considered to be a structural part of the aircraft and as such cannot be modified by the investigator.

The following wiring is provided to each wing:

- o 115V 400 Hz 3-phase at 7.5 amperes/phase
- o 1 28 VDC bus at 10 amperes
- o 1 Control wire from the cockpit (+28 VDC)
- o 2 Ground wires
- o 1 Set of 3 conductor twisted (3 wires)
- o 2 Sets of 3 conductor twisted/shielded (6 wires)
- o 2 Sets of 2 conductor twisted/shielded (4 wires)
- o 2 Spare single conductor wires

This provides for a total of 22 wires in each wing. A disconnect plug (Cannon part number CA3100RX28-115) is provided in the pylon of each tank for connection to the above noted wiring. The mating connector (Cannon part number CA3106RX28-11P or MS83723-24R2811N plug and MS83723-34N28 Backshell) is to be provided as part of the experimentors package.

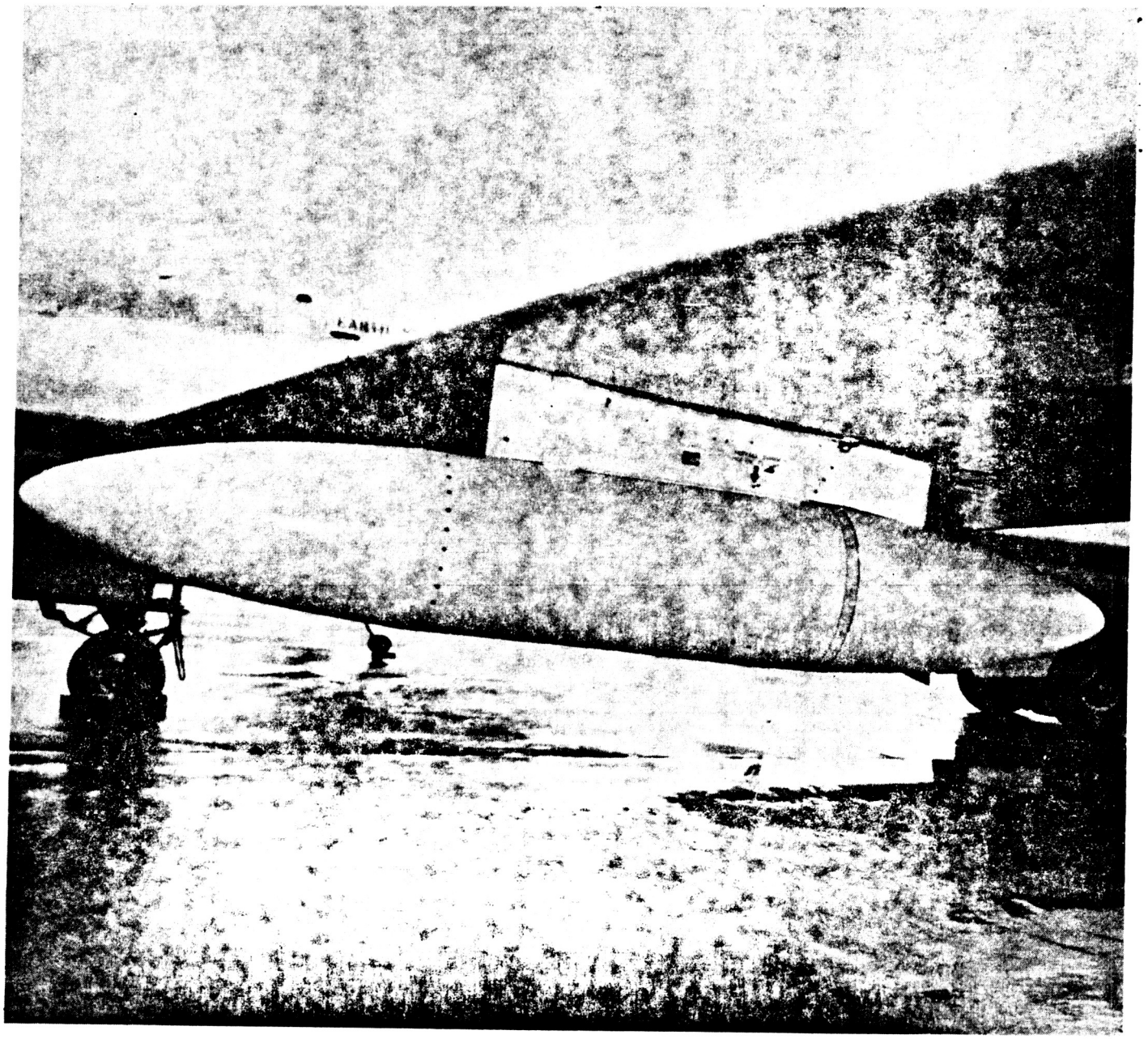


FIGURE D6 WING MOUNTED TANK

ONBOARD TAPE RECORDER

A fourteen (14) channel Bell and Howell M-14E magnetic tape recorder has been specially modified for installation on the U-2 aircraft. This modification enables the tape recorder to make six (6) sequential passes of two (2) tracks each at the six (6) speeds and related recording times noted in Figure D7.

The track sequencing of the six (6) pairs of data channels is accomplished by affixing a metallic strip at the beginning (BOT) and ending (EOT) of the 9,200 ft tape reel to automatically reverse tape direction and shift the tracks being recorded.

The recorder is capable of recording the following data:

- Analog data on each of the two (2) tracks
- Wide band FM Group II data on each of the two (2) tracks
- Serial Digital High Density (DHDE) Pulse Code Modulated (PCM) data on each of the two (2) tracks.

When there is a requirement for recording more than two (2) tracks of data simultaneously, the experimentor will be required to provide the proper analog to digital converters or multiplex devices which can provide a serial, digital stream of data acceptable to the modified M-14E recorder.

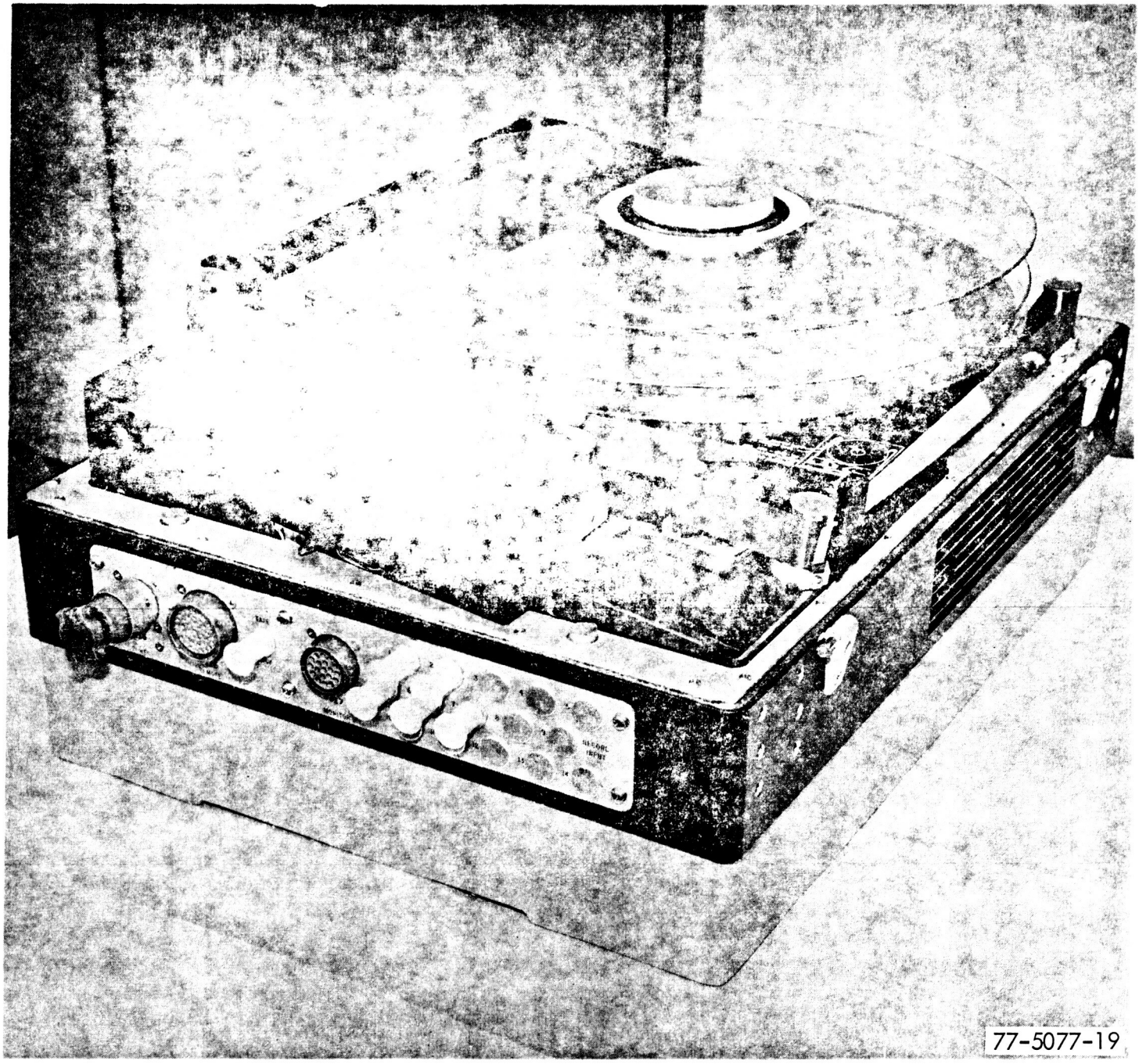
Some of the major restrictions necessarily imposed on the use of the recorder installation are as follows:

1. Normally the tape recorder will only be used with those experiments installed in theQ-Bay. Due to the type and quantity of wiring installed in the wing areas, wing pylon mounted experiments which plan to use the Q-Bay tape recorder, must provide a signal which is compatible with the existing wiring installed in the wings. Refer to Section DV for wiring details.

2. The experimentor is expected to provide a magnetic tape for all recording requirements. The type of tape for this recorder is identified as Bell and Howell part number 532711 magnetic tape, 1 inch wide x 9200 ft, processed to add beginning of tape (BOT) and end of tape (EOT) metallic stripping. One (1) inch wide instrumentation tape with a base thickness of 1.0 or 1.5 mil. type, Ampex 799 processed to add metallic BOT and EOT strips is an acceptable substitute tape.

3. Ground playback facilities at NASA Ames are very minimal and the experimentor should provide for data reduction facilities.

4. Due to the space available in the Q-Bay area, it will not be possible to fly the tape recorder with some experiments. The feasibility of installing the tape recorder with a specific experiment must be coordinated in advance with the NASA Ames Missions Manager.



TAPE-SPEED	TOTAL RECORDING TIME
120"/sec	1-1/2 hrs
60"/sec	3 hrs
30"/sec	6 hrs
15"/sec	12 hrs
7-1/2"/sec	---
3-3/4"/sec	---
1-7/8"/sec	---

FIGURE D7 ONBOARD TAPE RECORDER

DATA FACILITY

INTRODUCTION

The Airborne Instrumentation Research Project at NASA Ames Research Center operates two (2) U-2 high altitude aircraft to collect remote sensing and other data in support of NASA's Earth Observation Program. These aircraft provide a unique platform resource in support of NASA satellite programs. The functional objectives of the project are:

- o Collect underflight data in support of LANDSAT and SKYLAB investigations.
- o Provide sensor definition, test, and evaluation for future satellite sensor systems.
- o Collect In-Situ data in national programs of atmospheric and stratospheric research.
- o Demonstrate new techniques for the practical applications of remote sensing technology.
- o Support other Earth Resources programs in conjunction with various government agencies.
- o Collect data for disaster assessment.

The majority of data collected by the project consists of photographic imagery, and since the first data flight of August 31, 1971, well over 250,000 frames of photography have been acquired. This imagery represents extensive coverage of eastern and western states, occasional flights over the central states, most of the Hawaiian Islands, and portions of Alaska.

AIRP DATA FACILITY

The AIRP Data Facility is located at Ames Research Center. Visitors are requested to call in advance to schedule their visit. Group tours are also available. Operating hours are Monday through Friday, 8:15 a.m. to 12 noon, 1 p.m. to 4:30 p.m. Requests for data searches and other information are also accepted by phone (415) 965-6238.

Visitors will have access to the computerized Image Selection System (ISS), flight documentation records, microfilm copies of imagery (browse file), full format copies of imagery, and a variety of light tables and optical equipment for viewing purposes. Photocopying of imagery is allowed, but users must supply their own photographic equipment.

Reproductions of imagery are not available from the AIRP Data Facility. By established policy, all NASA earth resources imagery, both satellite and aircraft, is in the "public domain" and available through one or more Federal Dissemination Centers (FDC). The primary outlet for NASA aircraft imagery is the EROS Data Center (EDC) maintained by the U.S. Department of Interior in Sioux Falls, South Dakota. Order forms and price lists for the EDC photo products are available at the Data Facility.

DATA DOCUMENTATION

The AIRP Data Facility is responsible for the compilation and dissemination of several documentation products describing the collected data. These are available in limited quantities to serious data users by special request. Flight Summary Reports (FSR) are published for each data collection flight conducted by the Project. These brief reports list the sensors employed and the kinds of data collected on an individual flight and contain a Track Map showing the location of the individual data runs. Summary Catalogs are published every six months, representing a compilation of all data flights during the previous six months. Other special reports and documentation are prepared on a non-scheduled basis as required.

IMAGE SELECTION SYSTEM

As part of a complete, computerized data handling and management system, an Image Selection System (ISS) has been developed and is in operational use at the Data Facility. The ISS is an interactive, graphics oriented, computer based retrieval system for identifying remote sensor imagery data of interest to individual users.

The ISS design focuses on geographic location as the fundamental search parameter, with a capability to selectively filter down to coverage matching only certain user specified requirements. Selection parameters can limit the search to locate imagery of a particular scale, film type, data format, cloud cover, quality, spectral band, etc. By means of these selection criteria the total data base can be quickly and efficiently narrowed down to include only the "best" coverage for a particular purpose.

Parties desiring information about available U-2 coverage are requested to supply a specific locational description of the area they are interested in, preferably in geographic coordinates (latitude and longitude). They should also indicate what type of coverage is most suitable for their needs (scale, film type, etc.) or what purpose they intend to use the imagery for. This will help Data Facility staff members in developing the most appropriate search strategy.

Many data requests can be adequately handled by mail or phone, but if it is convenient, a personal visit to the Data Facility is generally most satisfactory. This will enable direct viewing of the computer selected imagery on microfilm, providing an ultimate verification stepnot obtainable otherwise. Requestors will be provided a computer printout listing of

of selected imagery and, if applicable, a hard copy record of the graphics display terminal showing the geographic orientation of the selected coverage.

IMAGE PROCESSING CAPABILITY

In support of scanner development and the application of satellite and aircraft data to the natural resource disciplines, the data facility operates and maintains a digital image processing system. The Interactive Digital Image Manipulation System (IDIMS) is designed for manipulation, analysis, interpretation and processing of a wide variety of image data. Images in digital format, such as LANDSAT data, are entered into the system directly. In addition to satellite data, the system is capable of processing aircraft data obtained from various U-2 scanners such as the Ocean Color Scanner and the Thermal Infra-red Scanner.

The system architecture is such that IDIMS may be used as a stand-alone system for processing and evaluation, either interactively or in batch mode, or as a pre and post processor for a larger computer facility.

IDIMS provides a variety of processing functions for the rectification, geometric correction and manipulation of multiband or single band digital data. Ancillary programs allow for digitizing area masks, control point selection and the generation of statistical calculations.

IDIMS is currently used by a wide variety of users in the NASA/Ames data facility for analysis of many different applications including land use classification and forestry studies.

SENSOR AND FILM TYPES

There are numerous photographic formats and film type data available from the NASA Ames based Airborne Instrumentation Research Project. A summary of these data are contained in Tables E1 and E2.

SENSOR TYPES

Format	Focal Length	Ground Coverage* (Nautical Miles)	Vertical Scale*	1" =	Remarks
70mm	1-3/4"	14 x 14	1:454K	37,833'	4 cameras-simultaneous exposure
3.5x3.5"	100mm	10.8 x 10.8	1:195K	16,250'	4 simultaneous exposures on 9" film
9 x 9"	6"	16 x 16	1:130K	10,833'	
9 x 9"	12"	8 x 8	1:65K	5,412'	
9 x 18"	24"	4 x 8	1:32.5K	2,708'	
18 x 18"	36"	5.3 x 5.3	1:22K	1,833'	Two 9 x 18" exposures

*@ 65,000 feet MSL

TABLE E1

FILM TYPES

Designation	Name	Color	B & W	Infrared
2402	Plus-X		X	
2424	Infrared Aerogrphic		X	X
2443/3443	Aerochrome Infrared	X		X
3400	Panatomic-X Aerial		X	
SO-242	Aerial Color	X		
SO-397	Ektachrome EF Aerographic	X		
SO-289	Flat Response Infrared		X	X
3414	High Definition Aerial		X	
SO-127	High Definition Aerochrome IR	X		X

TABLE E2